Preliminary Design Review

FCF Combustion Integrated Rack

April 14-15, 1999

National Aeronautics and Space Administration
John H. Glenn Research Center
Microgravity Sciences Division
Cleveland, Ohio 44135

Table of Contents

CIR Preliminary Design Review Agenda

Wednesday, April 14, 1999

Welcome/Introduction	**8:00 am**	
-General Background		**Ed Winsa /**
-FCF Overview / L1 Requirements		**Bob Zurawski**
-CIR PDR Purpose and Scope		
Requirements and Constraints	**9:00 am**	
-Combustion Science Requirements		**Karen Weiland**
-System Requirements		**Dennis Rohn**
-Resource Constraints		"
CIR System Description	**9:30 am**	
-CIR Overview		**Bob Zurawski**
-CIR Elements / Subsystems		**Marty O'Toole**
Break	**10:00 am**	
CIR Hardware Design	**10:15 am**	
-Rack / Rack Door / ARIS		**Malcolm Robbie**
-Optics Bench		**"**
-Combustion Chamber		**"**
-FOMA		**Dan Catalano**
-Environmental Control		**Rick Verbus**
Lunch*	**12:15 pm**	

* Boxed lunch delivered to meeting room.

CIR Preliminary Design Review Agenda

Wednesday, April 14, 1999

CIR Avionics -CIR Data Systems -Electrical Power	**1:15 pm**	**Tim Ruffner / Scott Lawyer**
CIR Software -S/W Architecture & Requirements -Software Design	**2:15 pm**	**Joe Ponyik**
Break	**3:00 pm**	
CIR Diagnostics -Image Processing Packages -Science Diagnostics	**3:15 pm**	**Nora Bozzolo**
Hardware Tour*	**4:30 pm**	**Bob Zurawski**
Day 1 Adjourn	**5:30 pm**	

* FCF/CIR mock-up at GRC Building 333.

CIR Preliminary Design Review Agenda

Thursday, April 15, 1999

Integration, Operations & Utilization	**8:00 am**	
-Flight Ops & Supporting Engineering		**Terry O'Malley**
-Ground Segment		**Diane Malarik**
-Utilization/ISS Interface		**Dwayne Kiefer**
Requirements Compliance	**9:00 am**	
-Experiment Models & DCE-II Overview		**John Haggard**
-Science Requirements Compliance		**Nora Bozzolo**
-Science Assessment		**Karen Weiland**
Break	**10:30 am**	
Miscellaneous Topics	**10:45 am**	**Bob Zurawski**
-CIR Metrics		
-HCR RFA Status		
-CIR Risk Assessment		
-CIR PDR Summation		
Lunch	**12:00 am**	
Management Discussions	**1:00 pm**	
-MSD Program Overview		**Jack Salzman**
-FCF/CIR Go-Forward Plan		**E. Winsa / R. Zurawski**
PDR Board Caucus / Splinter Meetings	**2:00 pm**	**PDR Board**
Summary Discussion / Feedback	**4:00 pm***	**All***

* Dinner gathering at GRC Guerin House after the review concludes.

Visitor Information

- Messages during the review will be received by ***Kim Wells*** at (216) 433-2855.
- The FAX machine number is (216) 433-8660. Please have facsimile transmissions sent to you in care of ***Kim Wells*** at GRC.
- Additional telephones are available in the lobby. Dial 7 then 1 and the (area code) + number.
- A boxed lunch will be delivered on Wednesday, April 14th. Please sign up at check-in Wednesday morning.
- A dinner gathering is scheduled at the Guerin House after the review concludes on Thursday, March 15th. Dinner, beverages and hor' dourves will be served.
- The cost is $15.00 to participate in the boxed luncheon and dinner gathering. Please pay at check-in Wednesday morning.

CIR PDR Participants

PDR Review Board:

Chairperson: **Melvin R. Carruth / MSFC**

Board Members:
Daniel J. Gauntner / GRC
John J. Givens / ARC
Daniel W. Hartman / JSC
David F. Mann / MSFC
Kerry L. Remp / GRC
Dr. Frank Schowengerdt / Colorado School of Mines
Dr. Mark P. Wernet / GRC
David W. York / GRC

Additional PDR Participants:

William Ramage / MSFC
Mick Culp / JSC
John Temple / JSC
Don Thomas / JSC
Mickey King / HQ

Welcome / Introduction

Ed Winsa

Bob Zurawski

FCF/CIR Contact List

- **FCF Project**

- Edward A. Winsa	FCF Project Manager	(216) 433-2861*
- Robert L. Zurawski	CIR Project Manager / FCF Deputy Manager	-3932
- Terence F. O'Malley	FCF Operations Manager	-2960
- Diane C. Malarik	FCF Ground Segment Manager	-3203
- Terri D. Rodgers	FCF Common Hardware Manager	-8740
- Dennis W. Rohn	FCF Chief Engineer	-2044
- Timothy J. Ruffner	FCF Avionics Lead	-2391
- Joseph G. Ponyik	FCF Software Lead	-8592
- Lily T. Facca	FCF Electrical Lead	-2833

- **Science, PI Hardware, Utilization Interfaces**

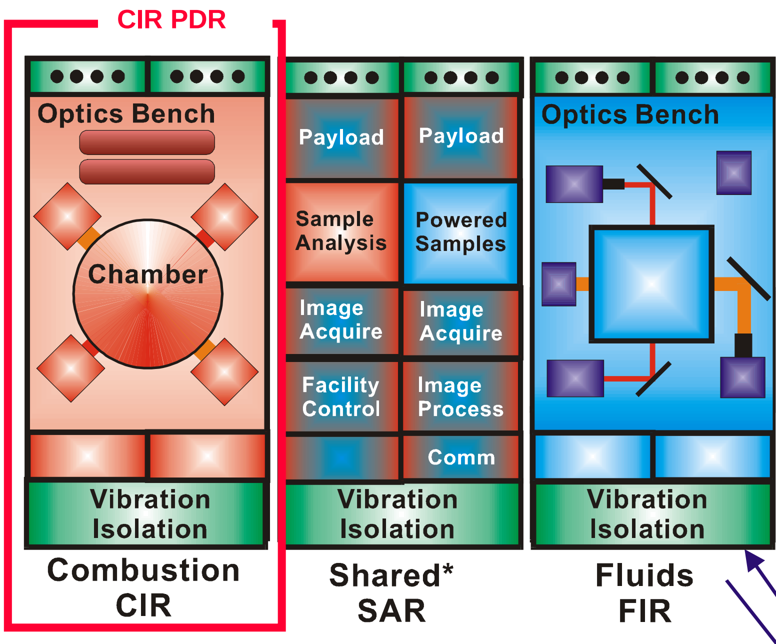
- Karen J. Weiland	FCF Combustion Facility Scientist	-3623
- John B. Haggard	Combustion PI Hardware Interface Manager	-2832
- Marsha M. Nall	Utilization Manager	-5374

- **CIR Development Team (Analex)**

- Martin A. O'Toole	CIR Project Lead	(216) 977-0090*
- Nora G. Bozzolo	CIR Chief Engineer	-0086
- Malcolm G. Robbie	CIR Mechanical/Structural Lead	-0131
- Daniel A. Catalano	CIR FOMA Lead	-0185
- Richard J. Verbus	CIR ECS Lead	-0192
- Frank A. Novak	CIR Software Lead	-0053
- Mike Casciani	CIR Electrical Lead	-0088
- Roger D. Helmick	CIR Diagnostics Lead	-0458
- Jon C. Wetherholt	CIR SE&I / Safety Lead	-0072
- Joel J. Knapp	CIR Operations Lead	-0173

* e-mail addresses for all above are: firstname.I.lastname@lerc.nasa.gov (e.g., robert.l.zurawski@lerc.nasa.gov)

FCF Scope



FCF is 2 Facilities Sharing 3 Racks

Flight Segment

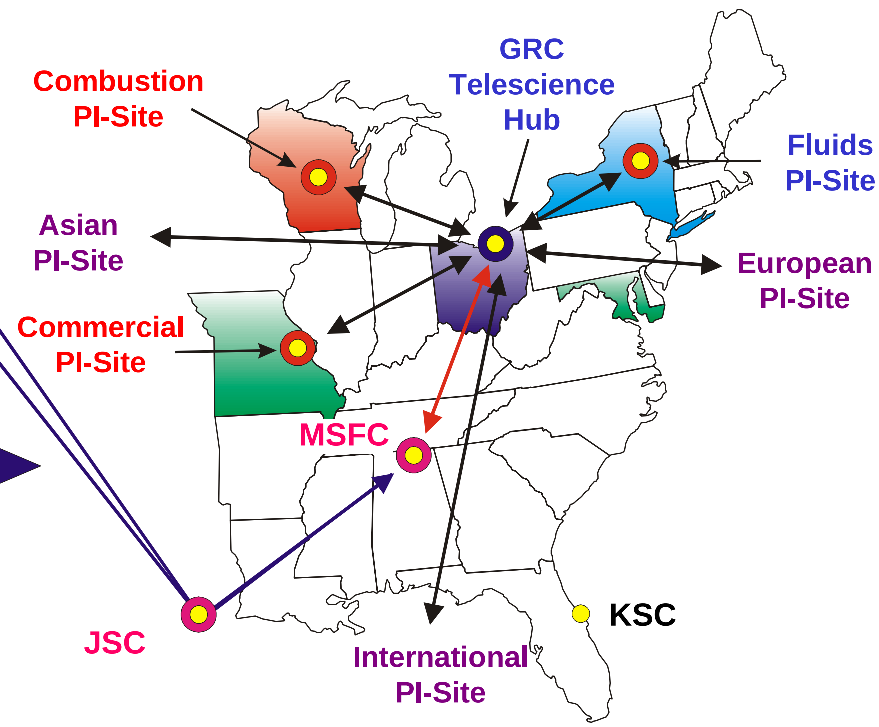
Space Station Based Equipment

- Fluid Physics Rack
- Combustion Science Rack
- Shared Rack
  - > Fluids, Combustion, and other payloads -- e.g. SAMS

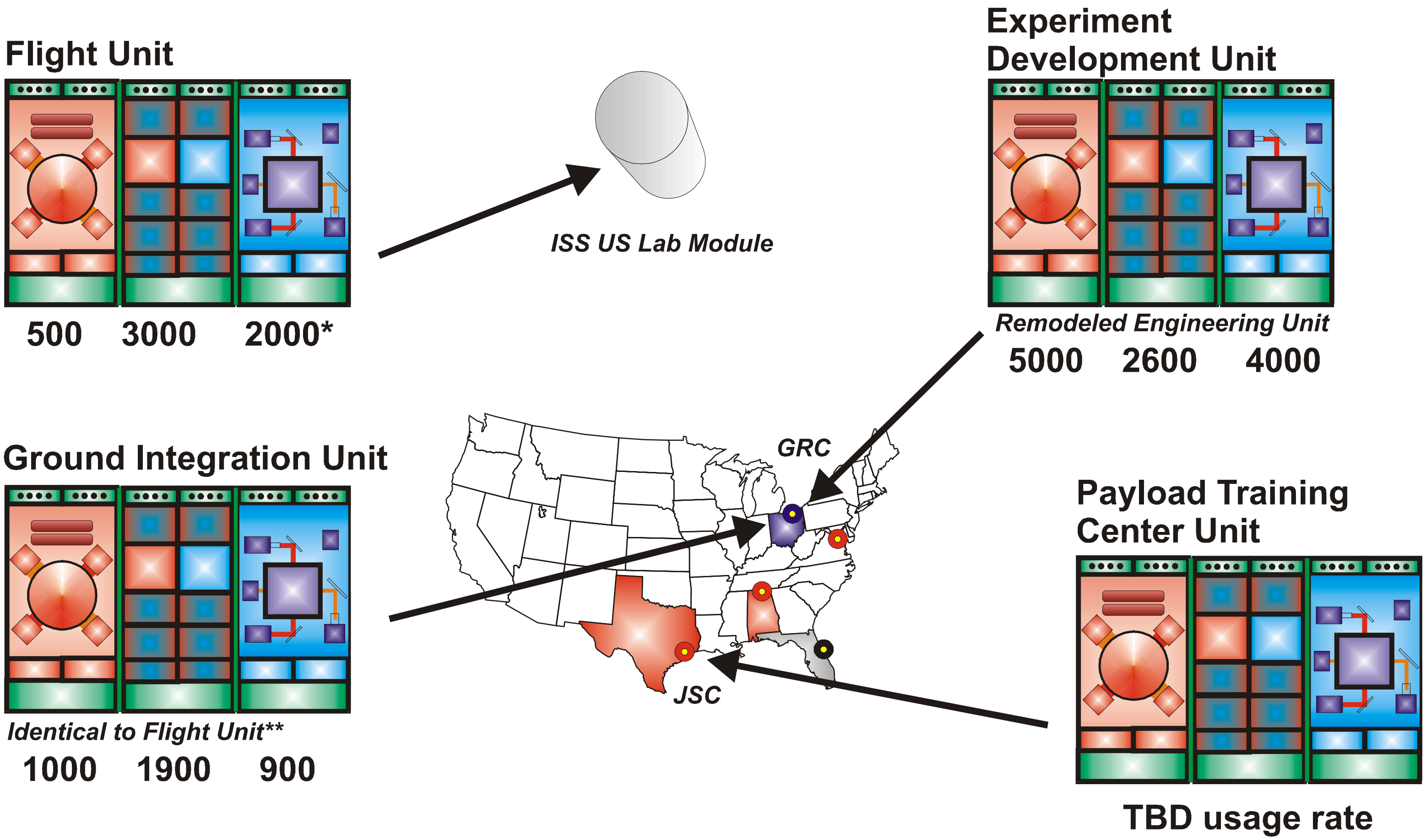
Ground Segment

Earth Based Operations

- PI Hardware development support
- Preflight PI Hardware checkout
- Telescience at PI-site and GRC TSC
- Astronaut Training



FCF Planned Flight-Like Units and Utilization Rates



* Estimated usage rate in hours per year is shown for each rack. The estimate is based on 20 fluids and combustion experiments per year (versus performance requirement of 10 minimum to 30 depending on resource availability). GIU and EDU may be underestimated. Estimate assumes ~30 percent of fluids experiments are run in center rack which is necessary to overcome scheduling conflicts both on earth and on ISS

** Aluminum Ground ISPRs.

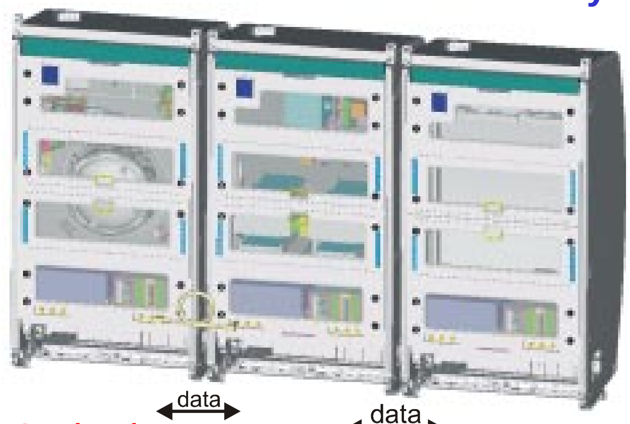
Space Station Fluids and Combustion Facility

Fluids and Combustion Facility

Combustion Integrated Rack (CIR) UF-3

Fluids Integrated Rack (FIR) UF-5

Shared Accommodations Rack (SAR) 2005



Combustion Science Rack

Shared Rack

Fluids Physics Rack

CIR and FIR operate independently until SAR.

Assembly of FCF is completed by the addition of the SAR. Fluid Physics and Combustion Science disciplines then share racks and mutually necessary hardware/software.

FCF will accommodate all envisioned experiments at the rate of 10 or more per year for the lifetime of the Space Station.

FCF RDR 10/96

FCF HCR 6/98

CIR PDR 04/99

FCF PDR
CIR CDR
FIR PDR
SAR PDR

FIR CDR

CIR Launch (UF-3)

SAR CDR

FIR Launch (UF-5)

SAR Launch

1996	1997	1998	1999	2000	2001	2002	2003	2004

Principal Level 1 Requirements*

- **FCF shall be a permanent ISS research facility located inside the ISS US Lab. It shall support HEDS Microgravity Science Program objectives by facilitating *sustained*, *systematic* Fluid Physics and Combustion Science experimentation for the lifetime of ISS.**
- **After ISS and FCF assembly complete, FCF shall permit a utilization rate of at least 5 *Basis Type*** Fluid Physics and 5 *Basis Type* Combustion Science experiments per year within budgetary and ISS resource constraints as defined at the FCF RDR. If resources should increase, FCF shall accommodate up to 15 experiments from each discipline per year.**
- **After ISS and FCF assembly complete, FCF shall accommodate at least 80 percent of the Fluid Physics and Combustion Science *Basis Type* experiments likely to be proposed for FCF.**

* Paraphrased -- the full text is contained in Chapter 1 of the FCF Science Requirements Envelope Document (SRED) which contains a total of 20 Level 1 requirements.

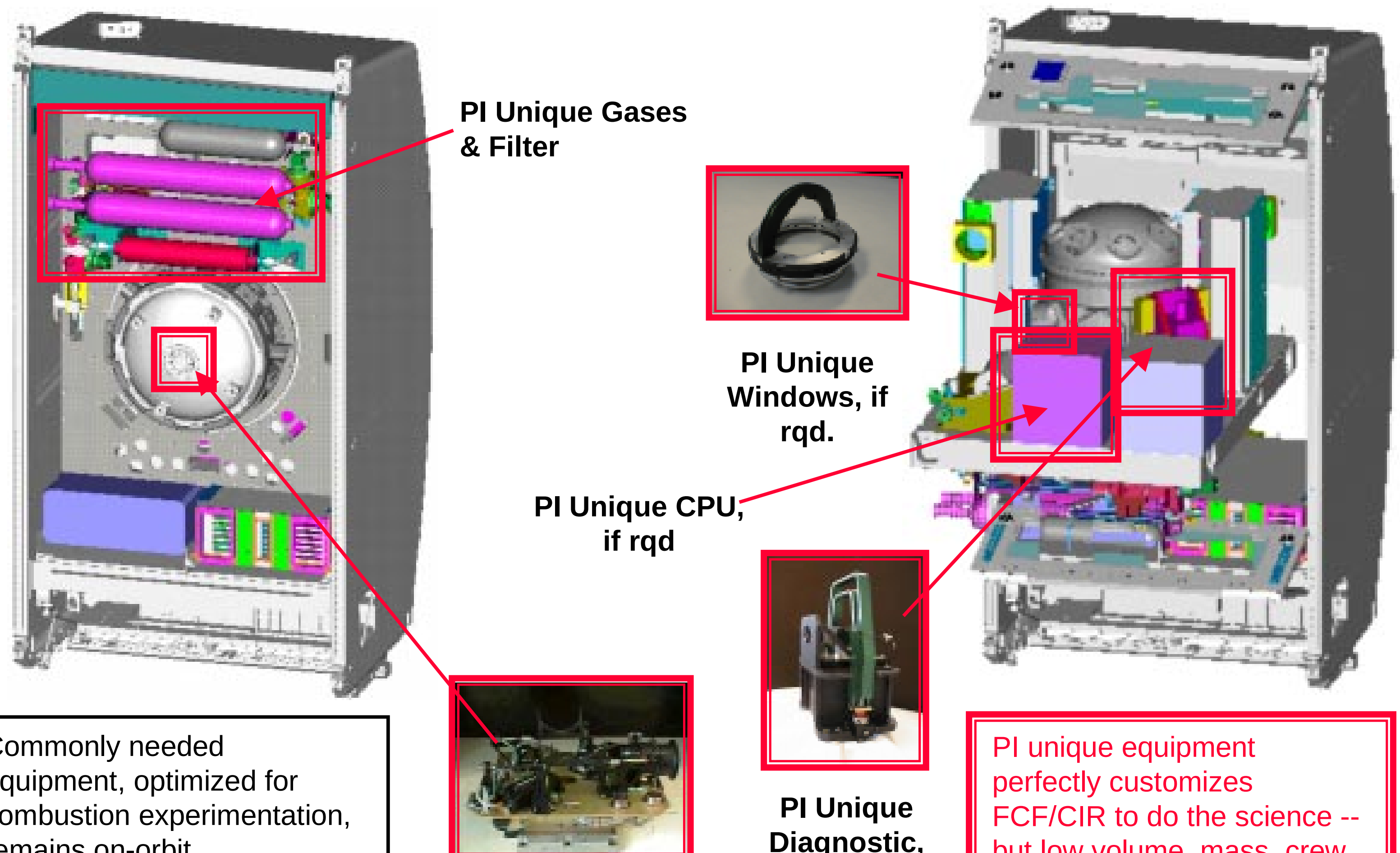
** To bound the FCF scope, discipline working groups have provided 14 Fluid Physics and 11 Combustion Science *Basis Experiments*. Their combined requirements roughly envelope the ranges of scientific requirements likely to be levied on FCF. Designing FCF to support these experiments should provide a reasonably flexible and practical facility capable of responding to the majority of experiment proposals. In effect, FCF will be customized to perform each new PI experiment by using a combination of FCF provided systems and an affordable amount of experiment unique hardware and software designed specifically for that PI.

FCF Principal Resource Constraints -- Design To

Resource	Units	Expected* Allocation	
Funds	M2005$/PI	< 3.3	(15 max)
Upmass	kg/flt	150 to 300	(700 max)
Flights	flt/yr	2 to 4	(4 max)
Stowage	racks	0.25 to 1.00	(1 max)
Crew Time	hr/wk	1 to 4	(8 max)
Power	Watts	1000 to 2000	(6000 max)
Coolant	kg/hr	28 to 56	(200? max)
Energy	kW-hr/yr	4500 to 9000	(? max)
Downlink	Mbits/s	1 to 3	(6-20 max)

* Allocation for entire 3 rack FCF -- must be shared by Fluids, Combustion, and FCF systems. ISS resources informally verified by ISS. Funds for PI unique hardware/software (PDR to PSR) in year 2005$.

FCF/CIR Customized for Each New PI Experiment

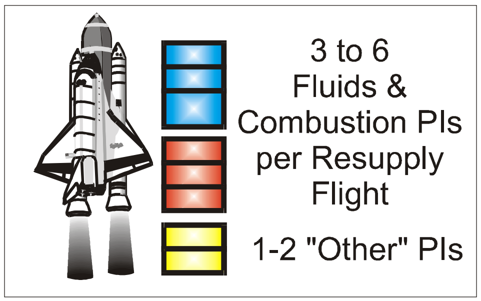


Commonly needed equipment, optimized for combustion experimentation, remains on-orbit.

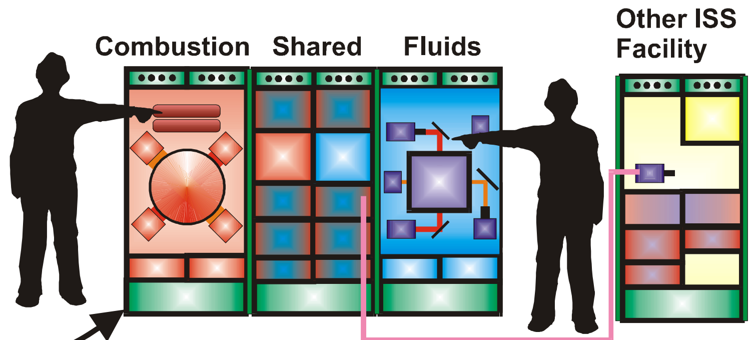
PI unique equipment perfectly customizes FCF/CIR to do the science -- but low volume, mass, crew time, and cost relative to non-facility approach.

FCF Operations Concept

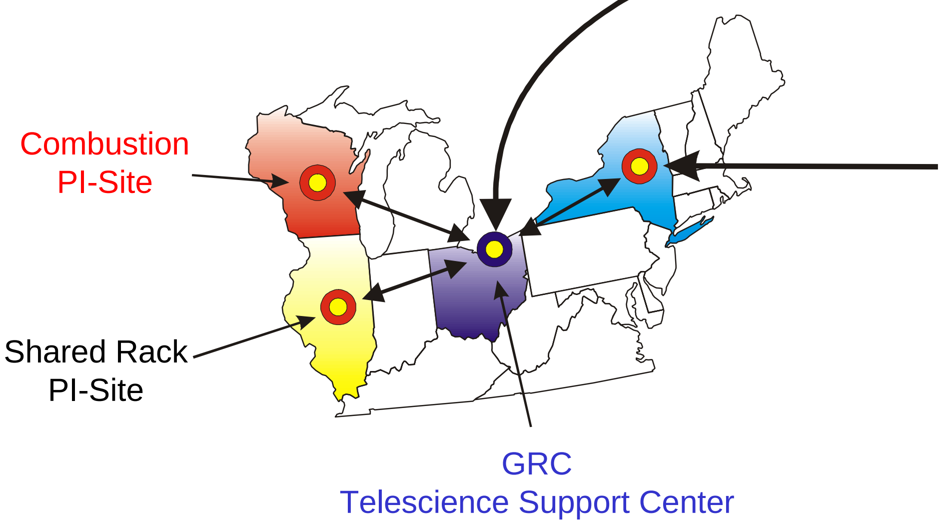
PI Hardware Launched



Astronaut has a month to set up combustion experiment while fluids experiment is functioning by Teleoperation and automation.

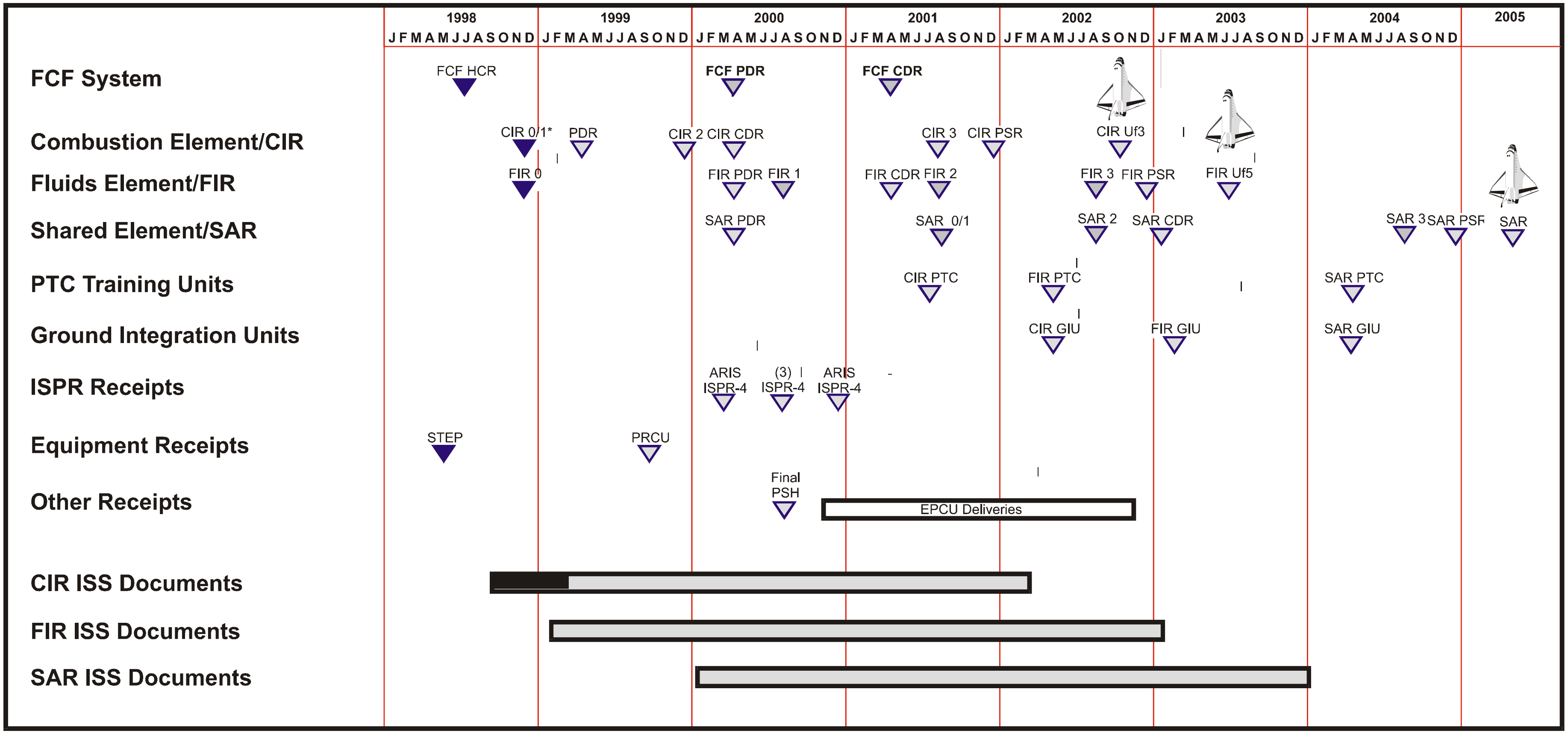


Then, Astronaut has a month to set up fluids experiment while combustion experiment is functioning by Teleoperation and automation.



Scientists receive and evaluate data at their home institution using their own staff members. Based on analysis, they direct changes in experiment protocol to maximize science.

FCF Development Schedule Milestones



* CIR 0/1, FIR 0, SAR 0 etc = phased safety reviews. U3, U5 = Utilization Flights. HCR = Hardware Concept Review.

FCF CoDR 12/94, FCF RDR 10/96

FCF Research Integration Schedule

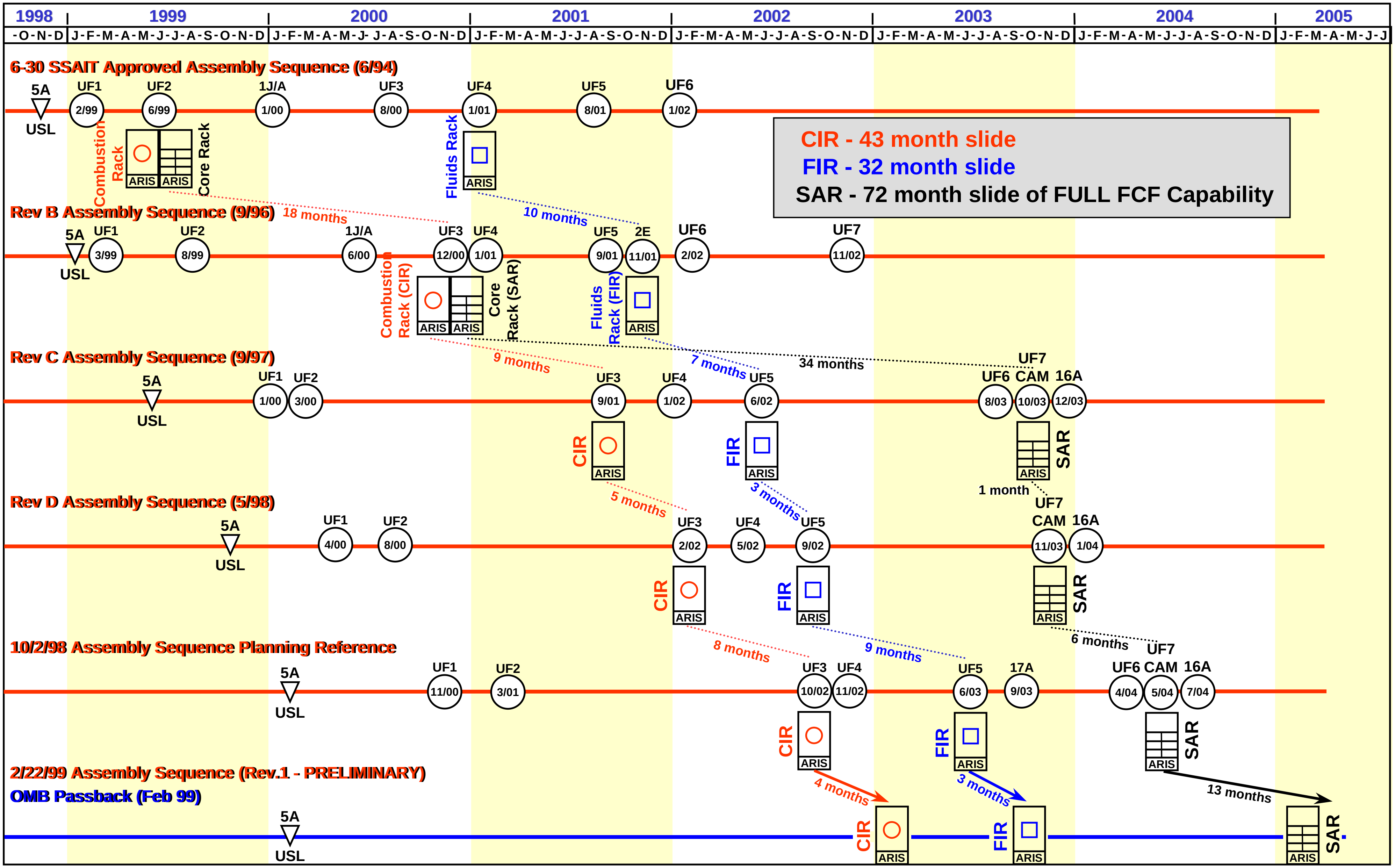
FCF Experiments

DATE/ QTR	4 / 00	11 / 00	3 / 01	12 / 01	10 / 02	6 / 03	9 / 03	1 / 04	4 / 04	5 / 04	1st		
Planning Period Increment (ISS)	P-2 ISS-2	P-3 ISS-3	P-3 ISS-4	P-4 ISS-5	P-5 ISS-?	P-5 ISS-?	P-6 ISS-?	P-6 ISS-?	P-6 ISS-?	P-6 ISS-?	P-? ISS-?	P-? ISS-?	P-? ISS-?
FLIGHT	6A	UF-1	UF-2	12A.1	UF-3	UF-5	17A	19A	UF-6	UF-7	LF-?	LF-?	LF-?
Facilities	EXPRESS Rack # 1, EXPRESS Rack # 2, ARIS	MSG			CIR, ARIS	FIR, ARIS						SAR, ARIS	
Combustion Science					MDCA-1, MDCA-2	MDCA-3, CFCF-A[1]		MDCA-4	CFCF-B[1]	MGCA-1	MGCA-2	CFCF-C[1]	FIST, Tarifa[1]
Fluid Physics	PCS[2]		PCS-TS		PCS-AS	LMM-1, LMM-2		LMM-3		LMM-4			μgSEG, Louge
Glovebox PI			CSLM-2							Marshall			
Glovebox GI			InSPACE										
Acceleration Measurement SAMS-II	ICU, RTS#1, RTS#2					ICU, ICU[3]							
Acceleration Measurement MAMS	MAMS												

Space Station Fluids and Combustion Facility

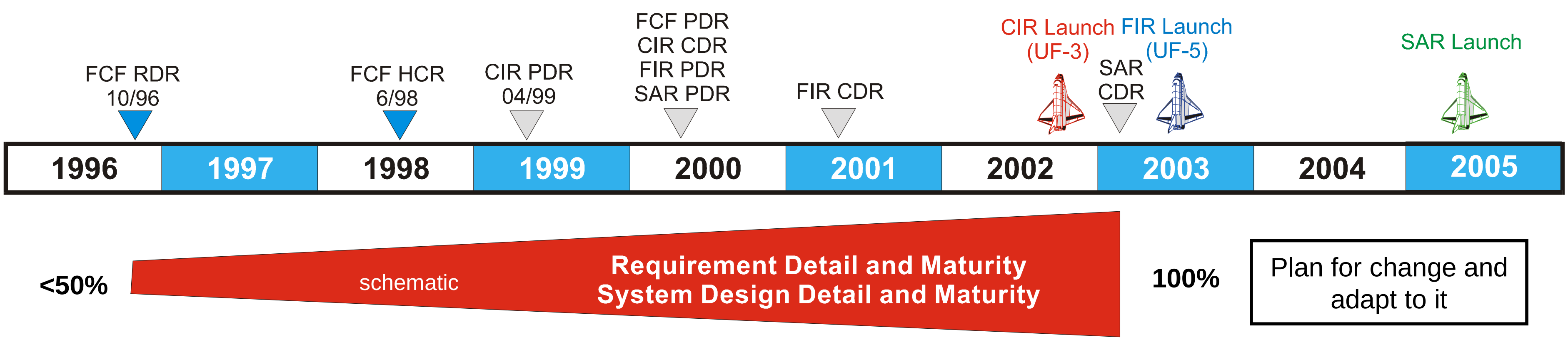
Glenn Research Center

Fluids & Combustion Facility

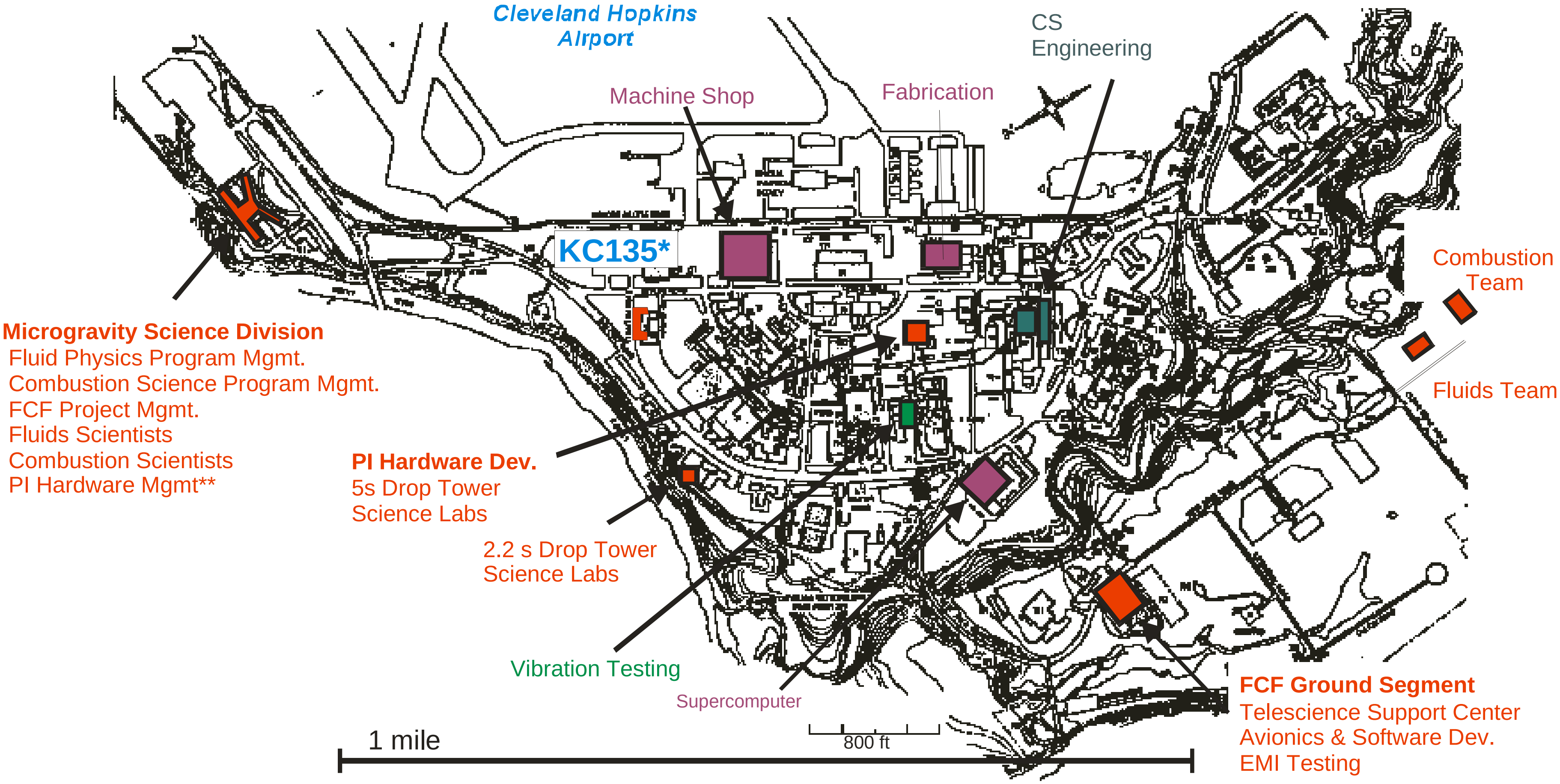


FCF Incremental Development Process

- **The Incremental Development Process (IDP) is a legitimate approach to System Development. It takes advantage of "excess" calendar time to reduce technical risk and cost while increasing the opportunities for creative new solutions. And, it mitigates the effects of change and uncertainty related to the "project environment".**
- **Oversimplified, IDP can be thought of as a form of prioritization and iteration**
  - **Develop highest level FCF requirements (FCF SRED & System Specification) but, initially, do not break these down further for the entire FCF system.**
  - **Deal first with CIR: Design CIR subsystems having "stable" requirements and interfaces first (CIR internal infrastructure and specific hardware/software modules), build, learn, then design CIR subsystems with "somewhat-stable" requirements and interfaces, build, learn, finally tackle the "unstable" areas.**
  - **Overall: Develop CIR, learn, modify requirements, develop FIR using better approaches, learn, modify requirements, develop SAR using best approach and latest technology (where that makes sense).**



FCF Project Teams and Facilities at GRC



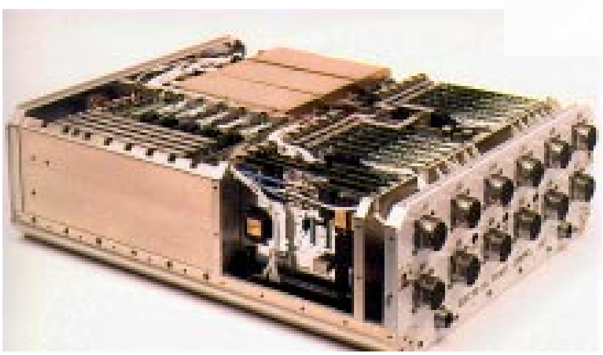
* KC 135 microgravity aircraft operates out of LeRC on a scheduled basis

** FCF anticipates PI hardware from a variety of sources in addition to GRC.

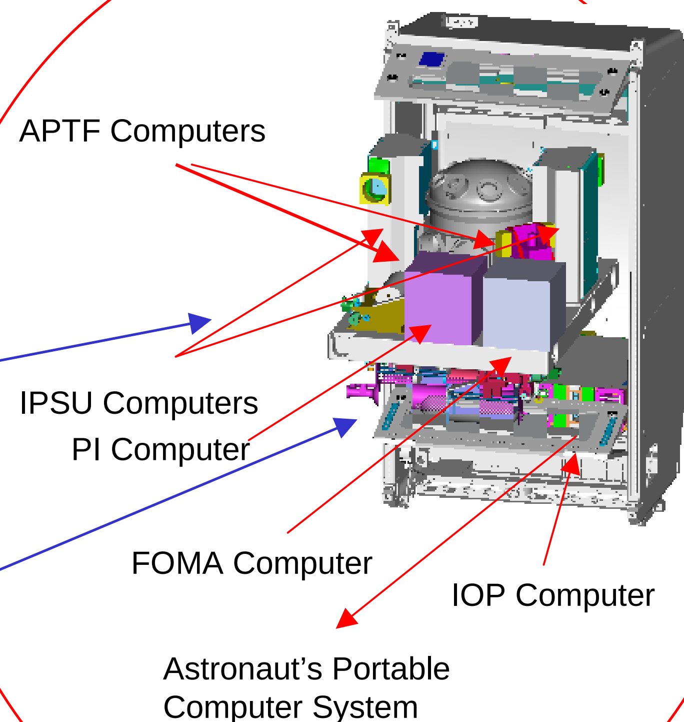
Some FCF Technical Achievements

CIR Human Factors Mockup

Modular Diagnostics -- Snap in/out in seconds



EPCU -- Hybrid Switch New Technology

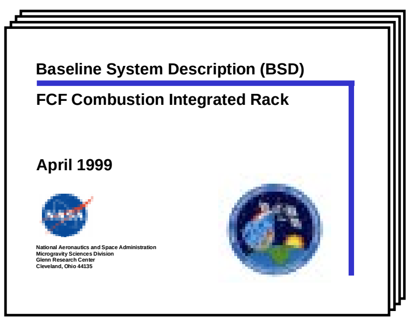


CIR computers tied together by EWT --NASA Software of the Year for 1998

CIR PDR Purpose

CIR Hardware & Software Designs

CIR BSD



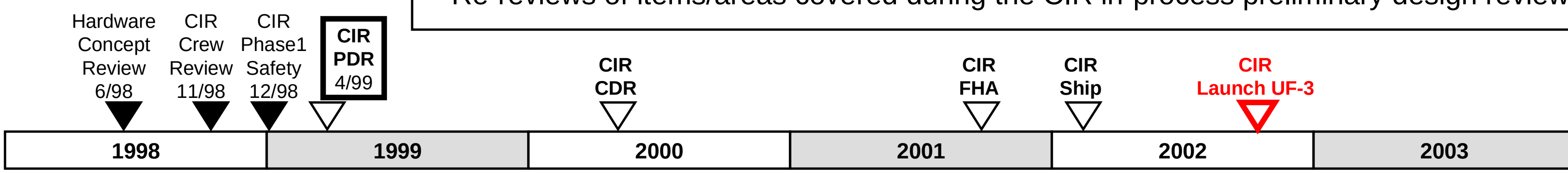
Review the CIR flight segment hardware & software preliminary design

PDR Key Questions:

- Is the proposed CIR hardware design approach technically sound to proceed with acceptable risk with incremental production and assembly of the CIR engineering model?
- Is the maturity of CIR software and the proposed software spiral development approach adequate for this phase of the project? Are the right software tools being employed?
- Based on an incremental development approach, are other aspects of the CIR, including interface definition, operations concepts, utilization plans, support engineering, science requirements compliance and technical documentation adequate to proceed with detailed design and development of the CIR?

PDR Does Not Involve*:*

- A review of flight/ground safety (CIR successfully passed Phase 1 Safety)
- A review of crew interfaces, operability or human factors engineering (Astronauts formally reviewed the CIR and endorsed its preliminary design).
- A review of the overall FCF flight or ground segment, except in relation to features and interfaces that the CIR needs to permit it to function with other FCF racks after they are deployed to ISS. (An FCF PDR is planned next year)
- Re-reviews of items/areas covered during the CIR in-process preliminary design review.



CIR PDR Board Charter & Responsibilities

Charter:

- Evaluate the progress and technical adequacy of the FCF CIR hardware and software preliminary design. Ensure that the CIR is ready to proceed to the next phase of development (detailed design and EM production), based on an incremental development approach.

Review Board Charge:

- Ensure that the CIR adequately addresses scientific requirements and other applicable requirements.
- Ensure that the CIR, functioning independently on-board ISS, will provide adequate capability to support initial microgravity combustion science investigations AND that the CIR design and its interfaces will permit it to function together with other FCF racks after they are deployed to ISS.
- Assess whether the CIR hardware design is adequate for the project to proceed with acceptable risk with the phased build of the CIR engineering model.
- Evaluate the maturity, proposed development approach and adequacy of tools being employed for the development of the CIR software.
- Based on an incremental development approach, assess the maturity of other aspects of the CIR, including interface definition, operations concepts, utilization plans, support engineering & technical documentation to confirm that the CIR is ready to proceed with the next phase of development.

Review Board Responsibilities:

- Provide a written report on the findings of the PDR to the FCF Project Office within four weeks of the review noting the strengths of the design, any deficiencies which the Board believes should be corrected prior to proceeding with the next phase of the project, and Requests for Action (RFAs) written by the Board to the FCF project based on the review.

Documentation

CIR PDR -- Key Documents:

- FCF CIR Baseline System Description (BSD) -- PDR Release, March 1999
- FCF CIR Preliminary Design Review Briefing Package -- April 14-15, 1999

FCF/CIR Documentation:

- **Requirements Documentation**
  - -FCF Science Requirements Envelope Document
  - -FCF System Specification
  - -CIR Software Requirements Document
  - -CIR Prime Item Development Specification
  - -FCF EPCU Specification
  - -CIR Payload Verification Plan
  - -CIR Compliance Matrix (Science Requirements)
- **Design Documentation**
  - -CIR Baseline System Description
  - -CIR Engineering Drawings, Schematics & Drawing Tree
  - -CIR Design Analysis Report
  - -CIR Engineering Model Test Plan
  - -CIR Acceptance Plan
  - -CIR Fracture Control Plan
  - -CIR Structural Design and Verification Plan
  - -CIR Mass Properties Control Plan and Report
  - -CIR Acoustic Control Plan
  - -CIR Microgravity Control Plan
  - -FCF Radiation Effects Study: Summary Report
- **SR&QA Documentation**
  - -CIR Phase 0/1 Flight Safety Compliance Data Package
  - -CIR Delta Phase 1 Flight Safety Data Compliance Data Package
  - -CIR Failure Modes and Effects Analysis
  - -CIR Quality Assurance Plan
- **Operations & Logistics Documentation**
  - -CIR Crew Review Plan
  - -FCF Integrated Logistics Support Plan
  - -FCF Ground Processing Plan
  - -CIR Simulator Requirements Document
- **Interface/Integration Documentation**
  - -ISS/CIR Hardware Interface Control Document
  - -FCF Payload Integration Agreement
  - -CIR/DCE-2 Interface Technical Agreement
  - -CIR Payload Accommodations Handbook
  - -CIR Mission Evaluation Request

Combustion Integrated Rack Documentation

- **CIR DOCUMENTS**
  - **REQUIREMENTS DOCUMENTS**
    - FCF-DOC-002 FCF SCIENCE REQ. ENVELOPE DOCUMENT
      - FCF-DOC-004 CIR COMPLIANCE MATRIX
    - FCF-SPEC-001 FCF SYSTEM SPECIFICATION
    - CIR-PLAN-0011 CIR PAYLOAD VERIFICATION PLAN
    - CIR-REQ-0001 CIR SOFTWARE REQUIREMENTS DOC.
    - FCF-SPEC-0010 FCF EPCU SPECIFICATION
  - **MANAGEMENT DOCUMENTS**
    - CIR PROJECT MASTER SCHEDULE
    - CIR-PLAN-0001 CIR CONFIGURATION MANAGEMENT PLAN *
    - CIR WORK BREAKDOWN STRUCTURE
    - FCF-PLAN-0007 FCF RISK MANAGEMENT PLAN
  - **DESIGN DOCUMENTS**
    - FCF-DOC-003 FCF BASELINE CONCEPT DESCRIPTION
      - FCF-DOC-003, App.A CIR BASELINE SYSTEM DESCRIPTION
    - CIR-PLAN-0007 FCF FRACTURE CONTROL PLAN
    - CIR-PLAN-0008 CIR STRUCTURAL DESIGN/VERIFICATION PLAN
    - CIR ENGINEERING DRAWINGS
      - 67212SFT0000 CIR DRAWING TREE
    - CIR-PLAN-0009 CIR ACCEPTANCE PLAN
    - CIR-PLAN-0015 CIR MICROGRAVITY CONTROL PLAN
    - CIR-PLAN-0002 CIR MATERIALS & PROCESSES CONTROL PLAN
    - CIR-RPT-0007 CIR MASS PROPERTIES CONTROL PLAN
    - CIR-RPT-0009 CIR DESIGN ANALYSIS REPORT
    - CIR PDR BRIEFING PACKAGE
    - FCF-RPT-0002 FCF RADIATION EFFECTS STUDY: SUMMARY REPORT
    - CIR-PLAN-0010 CIR ENGINEERING MODEL TEST PLAN
    - CIR-LIST-0001 CIR PARTS LIST
    - CIR-PLAN-0016 CIR ACOUSTIC CONTROL PLAN
  - **INTERFACE/ INTEGRATION DOCUMENTS**
    - CIR MISSION EVALUATION REQUEST
    - SSP-57117 FCF PAYLOAD INTEGRATION AGREEMENT
    - CIR-ICD-0001 CIR PAYLOAD ACCOMMODATIONS HANDBOOK
    - SSP-57217 CIR/ISS HARDWARE ICD
    - CIR-ICD-0003 CIR /DCE 2 TECHNICAL INTERFACE AGREEMENT
  - **OPERATIONS & LOGISTICS DOCUMENTS**
    - CIR-OPS-0001 CIR CREW REVIEW PLAN
    - FCF-PLAN-0006 FCF INTEGRATED LOGISTICS SUPPORT PLAN
    - FCF-PLAN-0002 FCF GROUND PROCESSING PLAN
    - CIR-REQ-0003 CIR SIMULATOR REQUIREMENTS DOCUMENT
  - **SAFETY, RELIABILITY, QUALITY ASSURANCE DOCUMENTS**
    - CIR-PLAN-A-0003 CIR PHASE 0/1 SAFETY COMPLIANCE DATA PACKAGE
    - CIR DELTA PHASE 1 SAFETY DATA PACKAGE
    - CIR-ANAY-0001 CIR FAILURE MODES & EFFECTS ANALYSIS
    - CIR-PLAN-0012 CIR QUALITY ASSURANCE PLAN
    - CIR PHASE 0/1 FLIGHT SAFETY REVIEW AGENDA

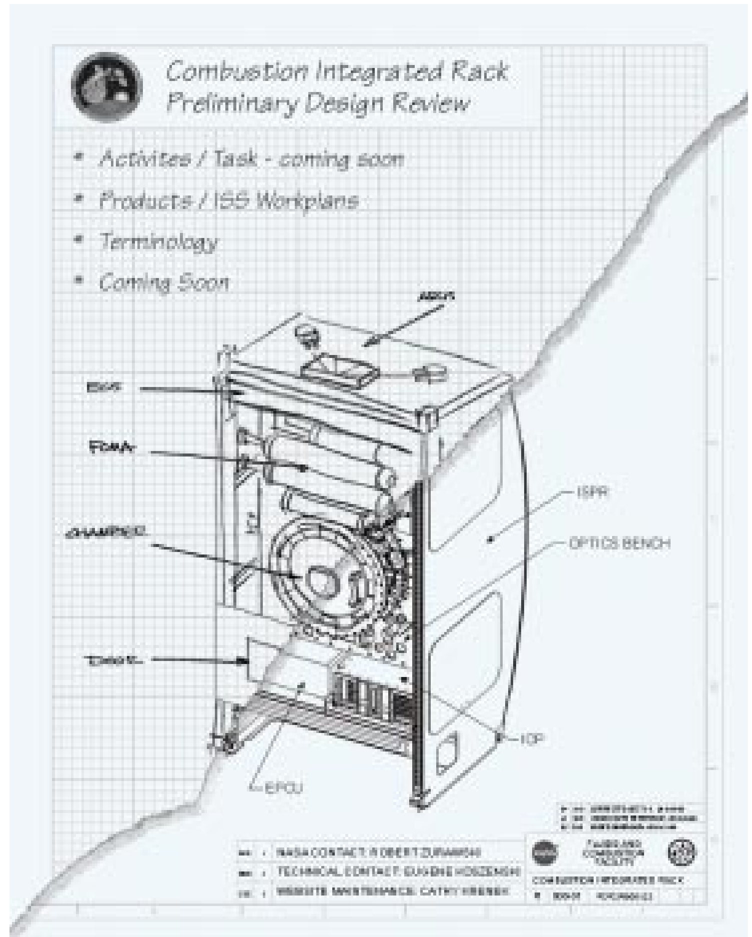
COLOR CODE

- READY TO BASELINE
- FINAL VERSION
- RELEASED DRAFT
- PRELIMINARY DRAFT

* Configuration Process has been established per CIR-PLAN-0001

CIR Preliminary Design Review Web Site

- **Review Item Discrepancies (RID) and comments against FCF/CIR technical documentation will be accepted, reviewed and considered by the project.**
- **RIDs and comments may be submitted electronically using a form that can be downloaded to your computer from the CIR PDR Web Site.**
- **RIDs/comments may be e-mailed to Eugene Koszenski at: Eugene.Koszenski@lerc.nasa.gov**



FCF/CIR Documentation can be found at the CIR Preliminary Design Review Web site at:
http://einstein.lerc.nasa.gov/fcfsite/cirpdr/index.html

CIR PDR -- In-Process Review Summary

Date	Reviewer(s)*	Item Reviewed	Review Summary	Status / Open Work
ISS/CIR Integration				
28-Sept-98 26-Mar-99	J. Temple / JSC W Geiger/JSC-TBE M. D'Onfrio/JSC S. Sitco/KSC R.Schlierf/KSC J. Beierle/JSC	**ISS/CIR Hardware Interface Control Document (ICD)**	<u>Hardware interfaces between CIR and ISS defined</u> and documented in coordination copy of ISS/CIR Hardware ICD, SSP 57217. Tabletop review of ICD held on 28-Sept-98. Final Coordination Copy complete.	Per ISS, FCF/CIR to be compatible with operation in both US Lab and COF. Exhaust venting, ITCS and mass of CIR are issues to be resolved for CIR compatibility with COF.
28-Sept-98 26-Mar-99	J. Temple / JSC W Geiger/JSC-TBE J. Ruiz/KSC W. Stevens/MSFC J. Beierle/JSC	**ISS/FCF Payload Integration Agreement**	<u>CIR steady state resource requirements documented</u> in FCF Payload Integration Agreement, SSP 57117,. Tabletop review on PIA held 28-Sept-98. Final Coordination Copy complete.	Per ISS, PIA OK at preliminary design stage of CIR development. Definition of resource allocations to CIR & expts. requires further definition by ISS.
3-Dec-98 (Monthly Updates)	M. Culp / JSC J. Temple / JSC T. Boatright / JSC	**CIR Development and Integration Schedules**	<u>Development and ISS integration schedules prepared for CIR.</u> Reviewed schedules at JSC on 3-Dec-98. Schedules submitted monthly to ISS common schedules database.	CIR development and integration schedules deviate from ISS PIM schedule templates due to CIR FHA date.
CIR Flight & Ground Safety				
24-Aug-98	J. Dollberg / KSC, GSRP B. Oyler / LSIM J. Temple/JSC	**CIR Phase 0/1 Ground Safety**	<u>Ground Safety TIM held</u> with J. Dollberg and B. Oyler August 24, 1998 to determine need for Phase 1 Ground Safety Review for CIR.	Phase 1 Ground Safety Review for CIR not required, per KSC GSRP.
1-Dec-98	D. O'Brien / JSC Payload Safety Review Panel L. Hill/PSRT	**CIR Phase 0/1 Flight Safety**	<u>CIR Phase 0/1 Flight Safety Review held</u> with Payload Safety Review Panel (PSRP) at JSC, Dec 1-3, 1998. All but two hazard reports signed at Phase 1 by PSRP.	Containment of toxic fluids (chamber sealing), back-off prevention of fluid fittings and controls on CIR vent line to prevent over-pressurization of ISS vent valve TBR at Delta Ph 1 review.
4-Mar-99	D. O'Brien / JSC Payload Safety Review Panel L. Hill/PSRT	**CIR Delta Phase 0/1 Flight Safety**	<u>CIR Delta Phase 0/1 Flight Safety Review held</u> with PSRP March 4, 1999. Dual seals on chamber and windows accepted for containment of critical fluids.	Identification of CIR hazards and hazard controls acceptable to PSRP. CIR successfully passed Phase 1 Flight Safety.

*** Note**: Reviewers shown are primarily external to GRC. All in-process PDR items also involved extensive internal review by the FCF/CIR team .

CIR Flight Safety

Phase 0/1 Flight Safety Review Successful (No significant problems)

- Phase O/1 Safety Review with PSRP in December 98 signed all but 2 hazard reports.
- Delta Phase 0/1 Safety Review in March 99 signed remaining 2 hazard reports.
- Chamber is acceptable for critical fluids.

Discussion with ISS and KSC Payload Safety Panel August 98

- Phase O/1 Ground Safety Review was considered not necessary due to limited GSE, limited operations, and experience
- Phase II will be first review

CIR PDR -- In-Process Review Summary

Date	Reviewer(s)*	Item Reviewed	Review Summary	Status / Open Work
CIR Operations, Crew Interface, Training				
2-Nov-98	D. Thomas / JSC M. Runco / JSC D. Brown, C. Walz, S. Wilson, W Scott, L. Morin / JSC C. Dailey / JSC	**CIR Crew Review**	CIR crew interfaces reviewed with astronauts to ensure human factors requirements are being met in the design of CIR. Validated operating philosophy and approach for CIR with the flight crew. Crew Review Plan documented in CIR-OPS-0001.	Per astronauts, design of optics bench has been modified to permit tool-less operation. EPCU labeling and indicator light positioning was also modified. Final Crew Consensus Report from review is pending.
12-Jan-99	A Johnston / MSFC W. Stevens / MSFC L. Frost / JSC J. Temple / JSC P. Williams/ MSFC C. Dailey / JSC	**CIR Simulator Requirements**	Defined CIR simulator that will reside at the SSTF/PTC to support training of the flight crew, POIC cadre, MCC-H flight controllers, FCF operations and PI teams. Tabletop review of CIR-REQ-0003 held 12-Jan-99.	CIR Simulator definition adequate at this phase of the project. Document will be updated, per ISS template.
14-Jan-99	PI Teams K. Watts / JSC B. Oyler / KSC L. Mundine /JSC	**Ground Processing**	Concept for ground processing FCF/CIR and its payloads defined, including activities at KSC. Concept documented in FCF Ground Processing Plan, FCF-PLAN-0002.	Simulators required for PI hardware testing to be resolved, as well as need for additional PRCU-type interface simulator for GIU and EDU testing.
22-Feb-99	R. Prange/JSC A. Evans/JSC	**Integrated Logistics Support**	Plan for Integrated Logistics Support of FCF/CIR defined and documented in ILSP, FCF-PLAN-0006.	ISS comments received. Assessment and response in work
CIR/PI Interfaces				
20-Nov-98	T. Oida / NASDA PI Teams	**CIR Payload Accommodations**	CIR Accommodations Handbook provides guidelines for payload developers for the design, fabrication and operation of PI experiment hardware in the CIR.	CIR PAH was released as a draft document on November 20, 1998. Document update required.
2--Nov-98	CIR Team DCE-2 Team	**CIR/DCE-2 Interface Technical Agreement**	Experiment-specific interfaces of the CIR, to accommodate the DCE-2 experiment are defined in the CIR/DCE-2 Interface Technical Agreement, CIR-ICD-0003.	The CIR/DCE-2 ITA is a precursor to an Interface Control Document (ICD) and Integration Agreements (IA) for CIR/DCE-2.

*** Note**: Reviewers shown are primarily external to GRC. All in-process PDR items also involved extensive internal review by the FCF/CIR team .

CIR Crew Review Overview

- The CIR Crew Review validated the CIR operations philosophy as well as the major design features of the hardware.
- The crew members were pleased with the approach and the ease with which the hardware could be manipulated.
- The crew space members had a number of recommendations including:
  - Changing to a optics bench deploy mechanism requiring no tools, and only one crew member.
  - Larger door latches
  - Use of Crew Restraints will be necessary for all operations assessed.
  - The new quick-latch mechanism will need to be evaluated.
  - The window replacement needs additional work

CIR PDR -- In-Process Review Summary

Date	Reviewer(s)*	Item Reviewed	Review Summary	Status / Open Work
CIR Requirements & Design				
21-Sept-98	Hornyak/JSC-BOE Geiger / JSC-TBE	**Materials & Processes Selection and Control**	Requirements for the selection of materials and processes (M&P) to fabricate CIR hardware defined in the CIR Materials & Processes Selection and Control Plan, CIR-PLAN-0002.	Update to reflect changes in requirements in latest revision of SSP 30233, MAPTIS database and safety critical structures documentation will be made in next revision of M&P plan.
19-Oct-98	W. Renegar / JSC S. Copeland / BOE T. Martin / JSC-LM W Geiger/JSC-TBE	**Structural Verification**	Factors of Safety, Design Loads, Structural Analysis/Test Methodology for CIR structures documented in CIR Structural Design and Verification Plan, CIR-PLAN-0008.	Will include preliminary list of working fluids in CIR pressurized systems in next revision of plan.
19-Oct-98	A. Shamala / JSC, PSRP W. Geiger / TBE	**Fracture Control**	Plan to prevent structural failure due to crack growth in critical FCF/CIR structures documented in CIR Fracture Control Plan, CIR-PLAN-0007.	Lists of fracture critical parts and safety critical structures to be added to plan for Phase II safety.
18-Dec-98	C. Schafer / JSC J. Beierle / JSC J. Temple / JSC M.Culp / JSC	**CIR Design Analyses**	CIR Preliminary Design Analysis documented in CIR Design Analysis Report, CIR-RPT-0009. First release of report includes structural analyses of optics bench and chamber, select thermal analysis, breadboard test results and ARIS control study.	Structural analysis of door, rack-level thermal analysis and other on-going analysis to be added in next report. Also include rack dynamics at higher frequencies in ARIS studies.
22-Dec-98	K. LaBel / GSFC P. Marshall	**Radiation Effects**	Assessed radiation-related risks to performance of FCF/CIR mission-critical hardware. Radiation effects TIM held with GSFC on 15-Dec-98.	Pursuing follow-on radiation effects testing in highest risk areas (i.e., FCF/CIR single board computers)
19-Jan-99	W Geiger/JSC-TBE L. Woodard/MSFC	**Failure Modes and Effects Analysis (FMEA)**	Identified possible failure modes and effects of the CIR design and critical items. FMEA/CIL documented in CIR-ANAY-0001.	No Open Work.

*** Note**: Reviewers shown are primarily external to GRC. All in-process PDR items also involved extensive internal review by the FCF/CIR team .

CIR PDR -- In-Process Review Summary

Date	Reviewer(s)*	Item Reviewed	Review Summary	Status / Open Work
CIR Requirements & Design (continued)				
16-Dec-98	Larson/MSFC-BOE Miller/JSC-BOE J. Allen - JSC-BOE Fialho/JSC-BOE N. Quraishi / JSC	**Active Rack Isolation Subsystem (ARIS)**	Work Plan developed in 8/98. Preliminary assessment of ARIS compatibility issues with CIR performed by Boeing and reviewed 22-Oct-98 and 16-Dec-98, respectively. Rack-to-rack umbilical concept feasibility assessed	Revise work plan. Complete study based on CIR preliminary design. Initiate mods for FCF/CIR ARIS and perform analyses of CIR configuration including rack-to-rack umbilicals.
20-Jan-99	K. Weiland / GRC J. Chambers / GRC PI Teams	**Combustion Chamber Design**	Review of CIR combustion chamber design held at GRC on 20-Jan-99. Design review covered window section, chamber lid, end caps, interface resource ring, breech.	Structural analysis of chamber updated based on review. Dual seals incorporated to contain toxic fluids. Proceeding with chamber EM mfg.
27-Jan-99	Hornyak/JSC-BOE K. Weiland / GRC D. Edwards / GRC PI Teams	**Exhaust Vent Package Design Review**	Review of CIR exhaust vent package held at GRC on 27-Jan-99. Design review covered exhaust manifold, vent manifold, pumps and adsorber cartridges.	CIR FOMA meets C6 SRED fluid flow requirement of 240 slm only with recirculation. Investigating options to increase flow duration and rate. Procuring/mfg. EVP EM components.
09-Feb-99	M. Culp / JSC Geiger/JSC-TBE J. Temple/JSC C. Schafer / JSC	**System Specification**	Performance, design, development and verification requirements for FCF documented. ISS review & comment - 2/99.	Update System Specification, per comments. Flow down requirements to CIR Specification.
10-Mar-99	E. Winsa / GRC MSD Tiger Team PI/Science Teams NCMR	**CIR Baseline System Description**	CIR design documented in Baseline System Description (BSD), FCF-DOC-003A. GRC Tiger team performed comprehensive review of BSD, resulting in Mar-99 release for PDR.	Baseline System Description will be updated periodically through the CIR development to reflect its current configuration/design.
14-Apr-99	R. Carruth / MSFC J. Givens / ARC D. Hartman / JSC D. Mann / MSFC Schowengerdt/UC Gauntner, Wernet York, Remp/GRC	**CIR PDR Board Review**	Review of CIR Preliminary Design by external, non-advocate Review Board to identify the strengths and any deficiencies in the design, prior to proceeding with Phase C/D.	Based on successful PDR Board Review, will proceed to detailed design phase of CIR development and production of CIR engineering model.

*** Note**: Reviewers shown are primarily external to GRC. All in-process PDR items also involved extensive internal review by the FCF/CIR team .

CIR PDR -- Board Review Ground Rules

- **The PDR Board Review is the culmination of a comprehensive, in-process review of the CIR preliminary design that has been on-going since September 1998.**
  - Aspects of the CIR preliminary design previously reviewed in detail during the in-process review will not be covered during this Board Review.
- **Consistent with a *two-day* format, this Board Review shall focus on highlights of the CIR design, operation and requirements compliance and results of the in-process preliminary design review.**
  - FCF/CIR team members are available for splinter sessions for detailed technical discussions, either during the Board review or as a follow-up to the review.
- **Requests for Action (RFA) will be accepted from Board members, addressing concerns with the CIR design or materials presented at this review.**
  - Only RFAs submitted through the PDR Board will be formally acted upon by the project (though all will be reviewed and considered).
  - It is requested that each potential RFA be discussed by the PDR Board and that RFAs submitted reflect both the consensus of the Board and the highest level concerns of the Board.
  - RFAs need not be written for issues/risks already identified and being tracked by the project (i.e., provided the Board is satisfied that the project is pursuing an adequate mitigation strategy).

Requirements and Constraints

Karen Weiland

Dennis Rohn

Microgravity Combustion Science Overview

Program objective is to obtain an understanding of the fundamental combustion phenomena for which low-gravity analysis and experimentation can be of use in

- **isolating the gravity-related mechanisms (e.g. buoyant convection)**
- **determining the influence of transport phenomena normally obscured by gravitational effects (e.g. thermophoresis, thermocapillarity, simple mass and thermal diffusion)**
- **creating desired symmetries and/or boundary and initial conditions (e.g. spherical droplets, negligible sedimentation)**
- **improving in-space system performance, principally spacecraft fire safety.**

Program goals:

- **To increase combustion efficiencies**
- **To decrease pollutant formation**
- **To produce valuable products by combustion synthesis**
- **To improve fire safety**

Microgravity Combustion Flight and Flight-Definition Experiments

Solid fuels with flow

- **<u>Solid Inflammability Boundary at Low Speed,</u> <u>Transition from Ignition to Flame Growth under External Radiation in 3D,</u> *Flammability Diagrams of Combustible Materials, Radiative Enhancement Effects on Flame Spread (also quiescent), Diffusion Flame Tip Instability, Flame Studies at Low Convective Flows (international)***

Droplets

- **Droplet Combustion Experiment, <u>Bicomponent Droplet Combustion Experiment,</u> *Sooting Droplet Combustion, Droplet Combustion in Low-speed Convective Flows***

Gaseous diffusion flames

- ***Flame Design, Spherical Diffusion Flames, Pulsed-fully Flames***

Gaseous premixed flames

- ***Cool Flames, Lean Turbulent Flames,* Water Mist (commercial)**

Reflight **<u>Phase B</u>** ***Phase A***

SRED Level 1 Requirements Summary for Combustion

- **FCF shall be a permanent on-orbit research facility in the US Lab of ISS and support sustained, systematic microgravity combustion science experimentation for the lifetime of the ISS.**
- **Each discipline (fluid physics and combustion science) shall be equal priority.**
- **FCF shall occupy no more than 3 ISPRs total plus 1 additional rack of stowage.**
- **FCF shall permit a utilization rate of at least 5 and up to 10 basis experiment type combustion science experiments per year. Up to an additional 5 users per year shall be accommodated for commercial and international users.**
- **FCF shall accommodate at least 80% of the microgravity combustion science experiments likely to be proposed.**
- **The basis experiments are defined in the SRED. Their requirements are represented collectively; meeting the requirements shall be done similarly.**
- **Requirements are of highest priority compared to desired capabilities.**
- **A requirement shall be stated as a functional capability, cause at least one basis experiment to fail if the requirement is not met, and can be verified.**

SRED Combustion Requirements Envelope Summary

Experiment Operating Conditions
- Physical Considerations
  - Test Section Dimensions
  - Initial Fuel State
  - Ignition Mechanisms
  - Acceleration and Vibration
- Initial Thermodynamic State
  - Pressure and Temperature
  - Oxidizer Composition
- Initial Fluid Dynamics State
  - Fluid Flow
- Test Matrix
  - Number and Duration of Tests

Experimental Measurements
- Evolution of the Combustion Region
  - Visible Imaging
  - Infrared Imaging
  - Ultraviolet Imaging
- Evolution of the Thermodynamic State
  - Temperature Point and Field Measurements
  - Pressure Measurements
  - Chemical Composition and Soot Measurements
  - Radiometry
- Evolution of the Fluid-Dynamics
  - Velocity Point Measurements and Full Field Velocity Imaging
  - Acceleration Measurements

Data Management
- Data Time Resolution
- Simultaneous Measurements

SRED Operations Requirements Summary for Combustion

Experiment Development
- **FCF simulators**
- **Mission timeline sequence testing**
- **Calibration, verification, and functional test data**
- **Functional performance verification**

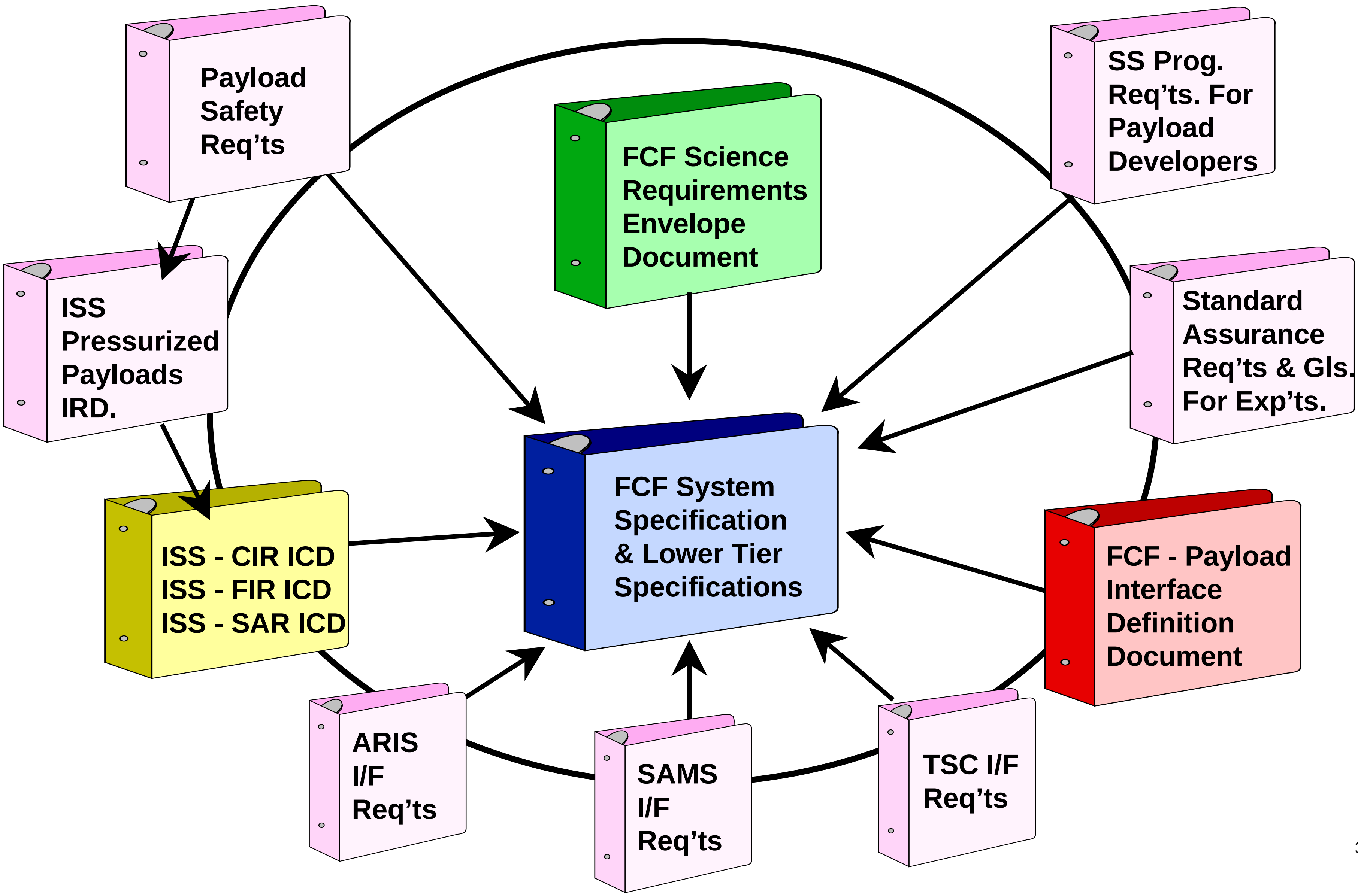
Flight Operations
- **Environmental parameters and ISS data**
- **Near-real-time data and imaging channels downlink and near-real-time command up-link**
- **Recording, protecting, and transferring science data on-orbit**
- **Identification of off-nominal conditions**
- **Provision of custom hardware and software required to analyze data**

Post-Flight Operations
- **Return of PI-provided equipment, samples, and data**
- **Availability of all data generated on flight**
- **Delivery of hard copy format of the data to the PI within 60 days.**

Modeling of Combustion Basis Experiments

- **SRED requirement P9: After ISS and FCF assembly complete, FCF shall accommodate at least 80 percent of the microgravity combustion science experiments likely to be proposed for FCF. FCF compliance shall be shown by conceptual experiment layouts and analysis indicating that 80 percent of the combustion science Basis Experiments could be accommodated by FCF facility capabilities when augmented by PI hardware capabilities.**
- **Real experiments with Science Requirements Documents were substituted for the basis experiments in most cases to give a realistic look to this compliance effort. Project managers, project and facility scientists, and CIR design team participated.**
- **Hardware design presentation will present compliance with individual SRED requirements. SRED requirements are shown in black, gray, or white boxes. In some cases, the SRD requirements are shown in red. The CIR capabilities are shown in various colored boxes on the graphs.**
- **Modeling results for each experiment will be presented separately from the hardware design presentation to show the level of compliance with SRED requirement P9.**

FCF System Requirements



FCF Requirements Documentation Status

- **SRED - HQ approval.pending, awaiting incorporation of a few requested changes.**
- **System Specification - Final review comments being incorporated, document will then be submitted for signature**
- **FCF Payload IDD - Draft version started, with a priority of CIR, FIR and then SAR interfaces**
- **ISS-CIR ICD - Draft prepared, reviewed and updated. Document will remain in draft form (coordination copy) until CDR timeframe**
- **CIR PIDS - Rough draft prepared. In process of being updated**
- **CIR to SAR I/F Requirements - interface concept defined, documentation not started**
- **SAMS I/F Requirements - Interface being defined, but formal documentation not started**
- **TSC I/F Requirements - interface definition awaiting further definition of FCF Ground Segment**
- **ARIS I/F Requirements - SSP 57005 provides interface requirements, currently in draft form by ISS**

ISS Requested Resources For CIR

Resources		CIR Resource Requirements
On-Orbit Volume (rack equivalent volume cubic feet)		2.0 ISPRs
Up Mass (kilograms per year)		750
Down Mass (kilograms per year)		750
Up Volume (rack equivalent volume cubic feet per year)		1.0
Down Volume (rack equivalent volume per year)		1.0
Energy (kilowatt hours per year)		1800
Crew Time (hours per year)		140
Communications Downlink (terabits per year)		9.0
Communications Uplink (terabits per year)		7.0×10^{-4}
Late/Early Access (launch/return/both/none)		N/A
Support Equipment (list):	Still Camera Standard Video Camera General Purpose Handtools Restraints and Mobility aids Cleaning Equipment	Houskeeping Equipment Compound Microscope Digital Multimeter Portable Light ISS Standard Power Tool
Other Coordinated Payloads (payload name)		SAR / SAMS
Additional Requirements (specify):	Power 3KW Vacuum Exhaust Service Vacuum Service Gaseous Nitrogen Moderate Temperature	Loop High Data Rate Lilnk Ehternet 1553 bus Video ARIS

* This Table shows the FCF PIA (Table 8.1.1-1)* requested CIR annual resource requirements
* The ISS has yet to sub allocate resources to the Research Programs
* The CIR MER (8/19/98) defines the rack resource requirements for the initial increment

* Note that the FCF PIA is not baselined, but coordinated as a preliminary payload submit

CIR Systems Description

Bob Zurawski
Marty O'Toole

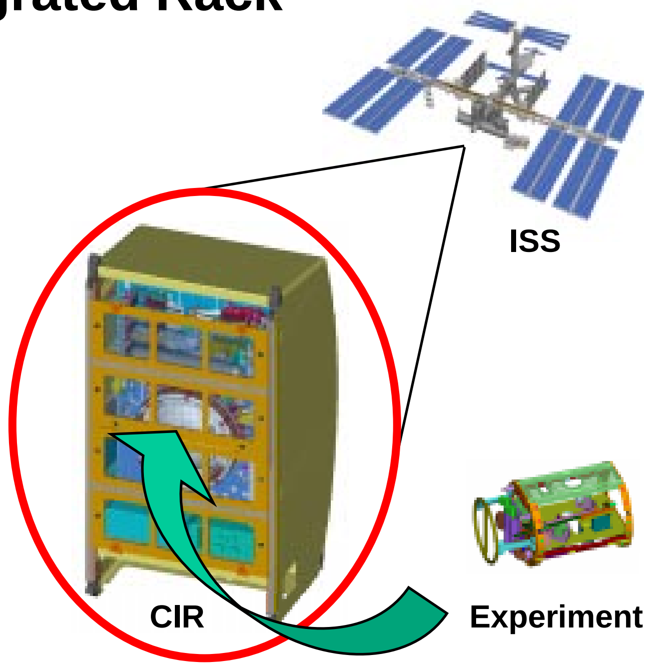
ISS FCF Combustion Integrated Rack

Mission

- Develop a modular, multi-user facility that will support a diverse range of microgravity combustion science investigations on board the International Space Station.

Concept and Key Design Drivers

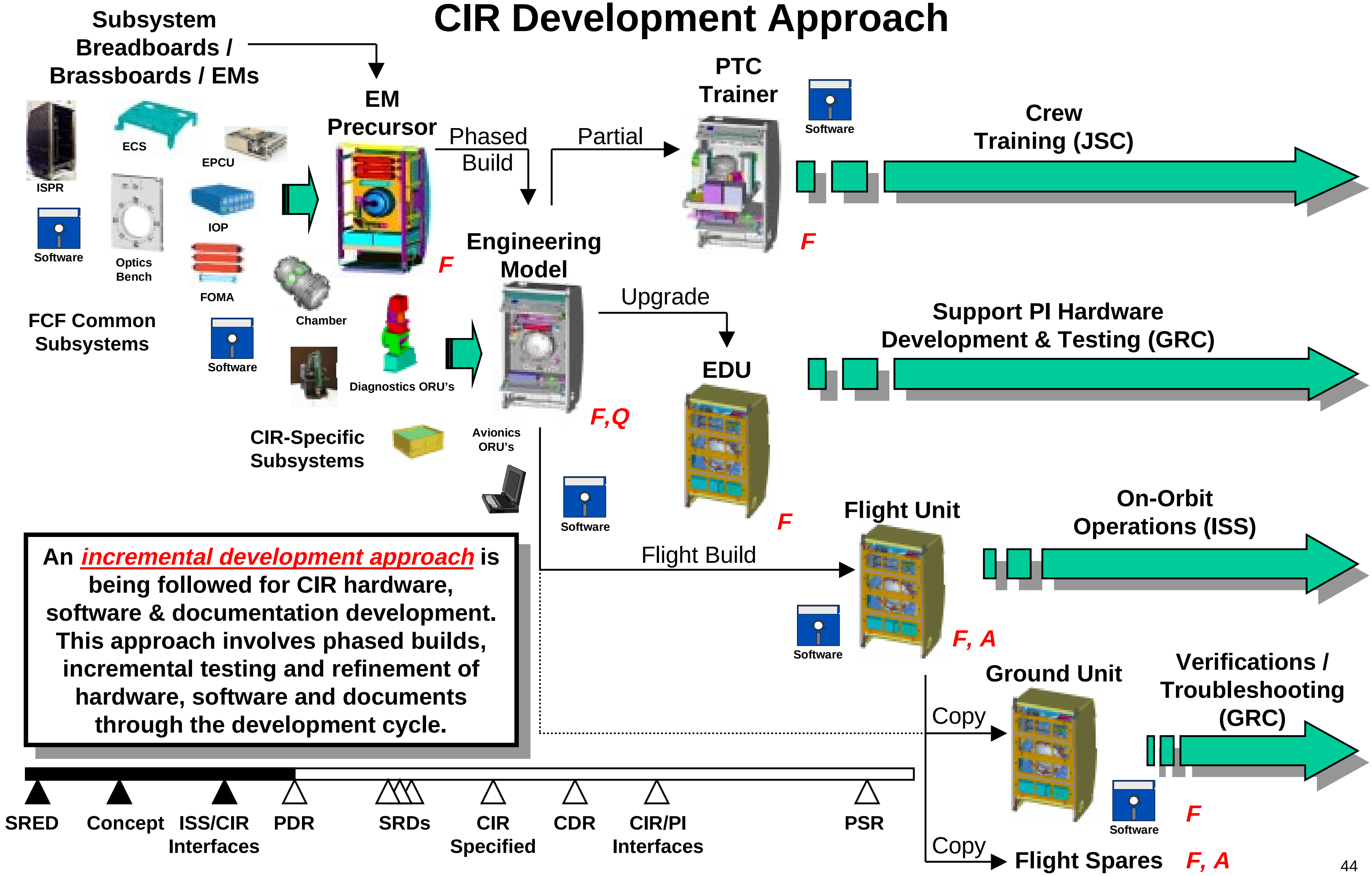
- Provide the majority of the required hardware and infrastructure to perform combustion science investigations in ISS (the remaining equipment is experiment specific).
- Provide a modular, flexible design to support many combustion experiments with diverse science requirements, as defined in the SRED and individual experiment SRDs.
- Design for permanent installation in ISS. Key components are on-orbit replaceable to enable upgrades, incorporate new technology and/or provide for on-orbit maintenance during the >10 year life span of the facility.
- Operate initially in ISS as an independent rack. After other FCF racks are deployed to ISS, operate in conjunction with those racks to leverage their capabilities and services to meet Level 1 science requirements.
- Conserve ISS resources, thereby maximizing research opportunities and science return from ISS.
- Design for highly autonomous operation to minimize the crew time needed to set up, perform & acquire scientific data from experiments.



Microgravity Combustion Research Areas

- Laminar Flames
- Turbulent Combustion
- Smoldering Combustion
- Reaction Kinetics
- Condensed Phase Organic Fuel Combustion
- Flame Spread and Fire Suppressants
- Droplet and Spray Combustion
- Soot and Polycyclic Aromatic Hydrocarbons
- Materials Synthesis

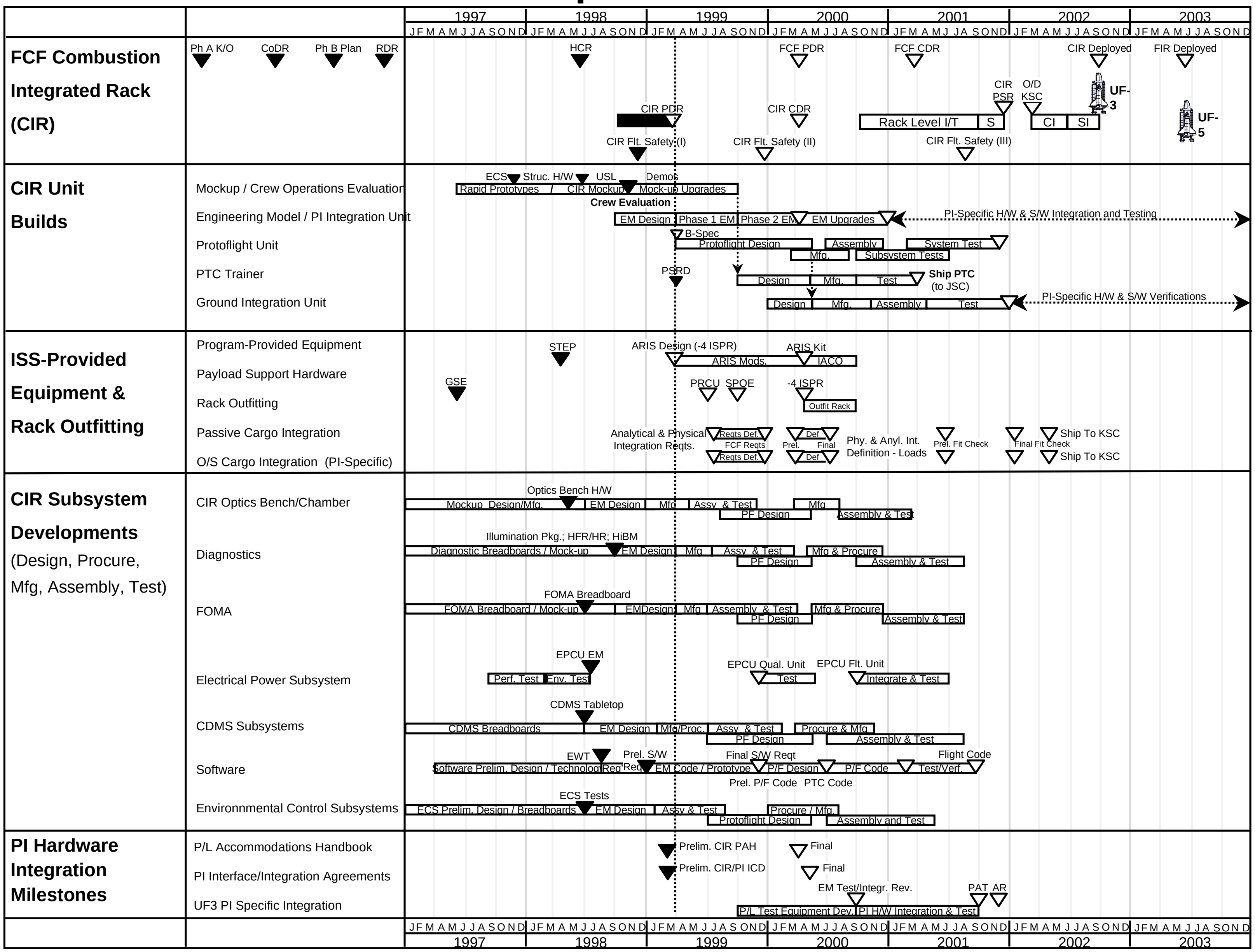
CIR Development Approach



An *incremental development approach* is being followed for CIR hardware, software & documentation development. This approach involves phased builds, incremental testing and refinement of hardware, software and documents through the development cycle.

Note: F=Function/Performance Testing, Q= Qualification Testing, A=Acceptance Testing

CIR Development Schedule



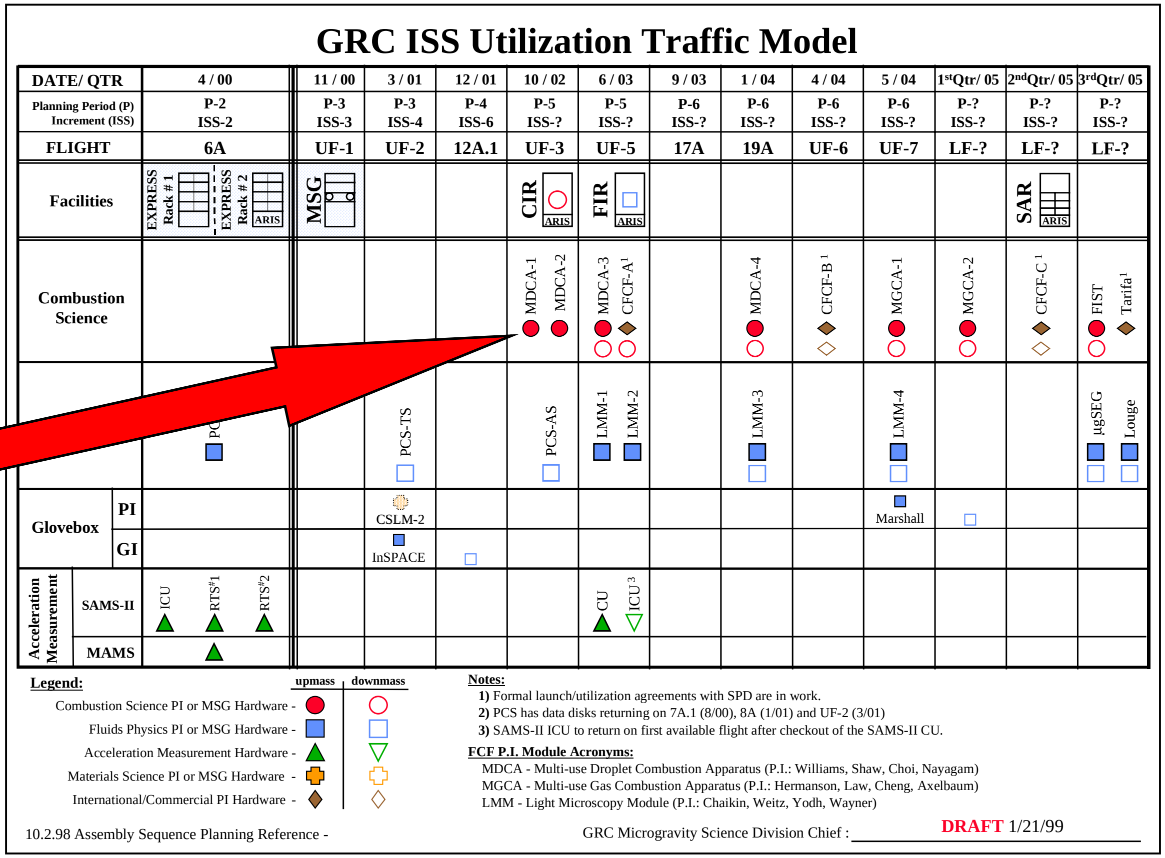
CIR/Combustion PI Launch Manifest

- The following shows the Preliminary GRC Traffic Model derivative of the Assembly Sequence, highlighting the CIR and its sub-rack payloads.

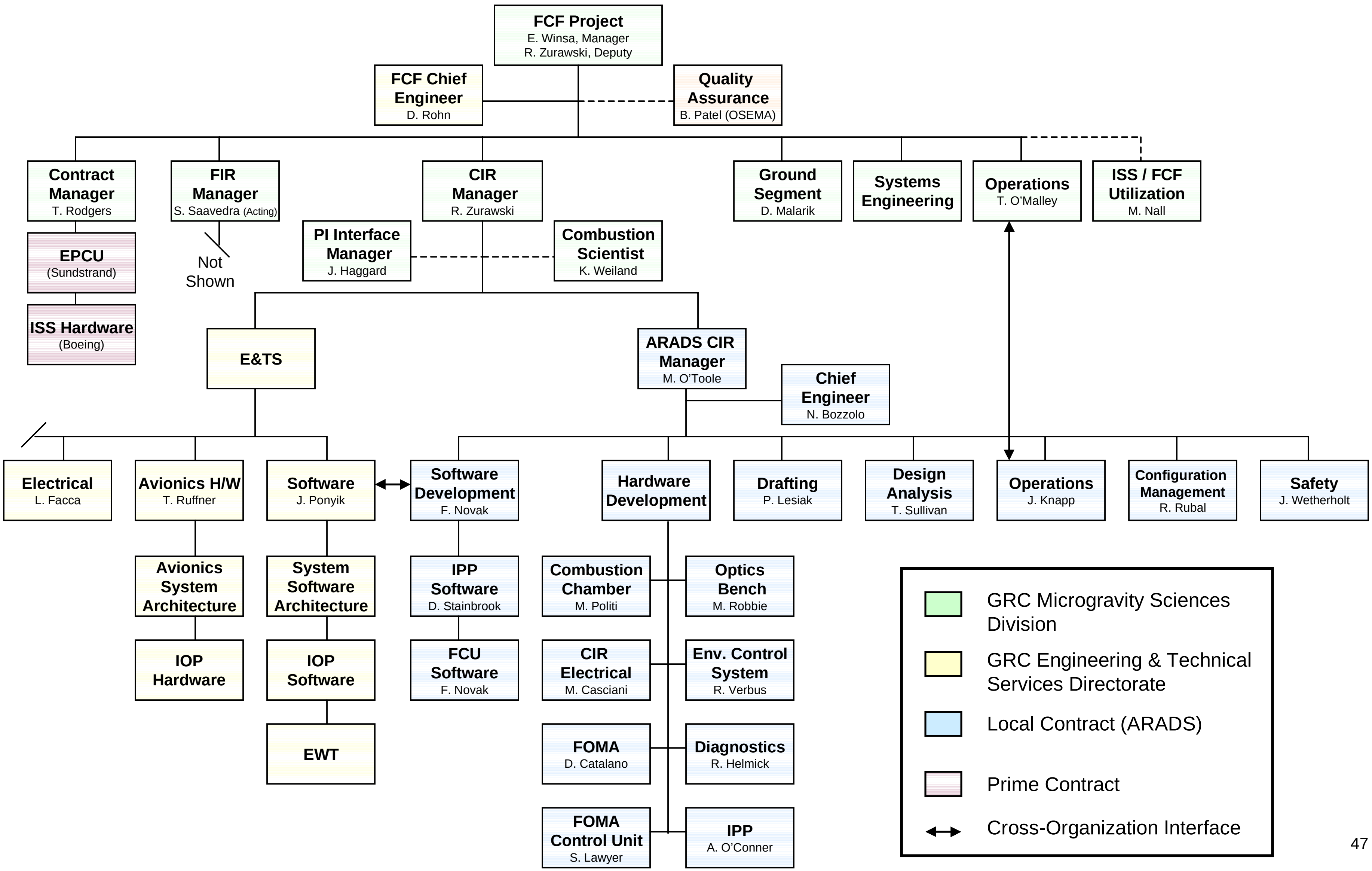
10/2/98 Assembly Sequence Planning Reference

seline Assembly Sequence

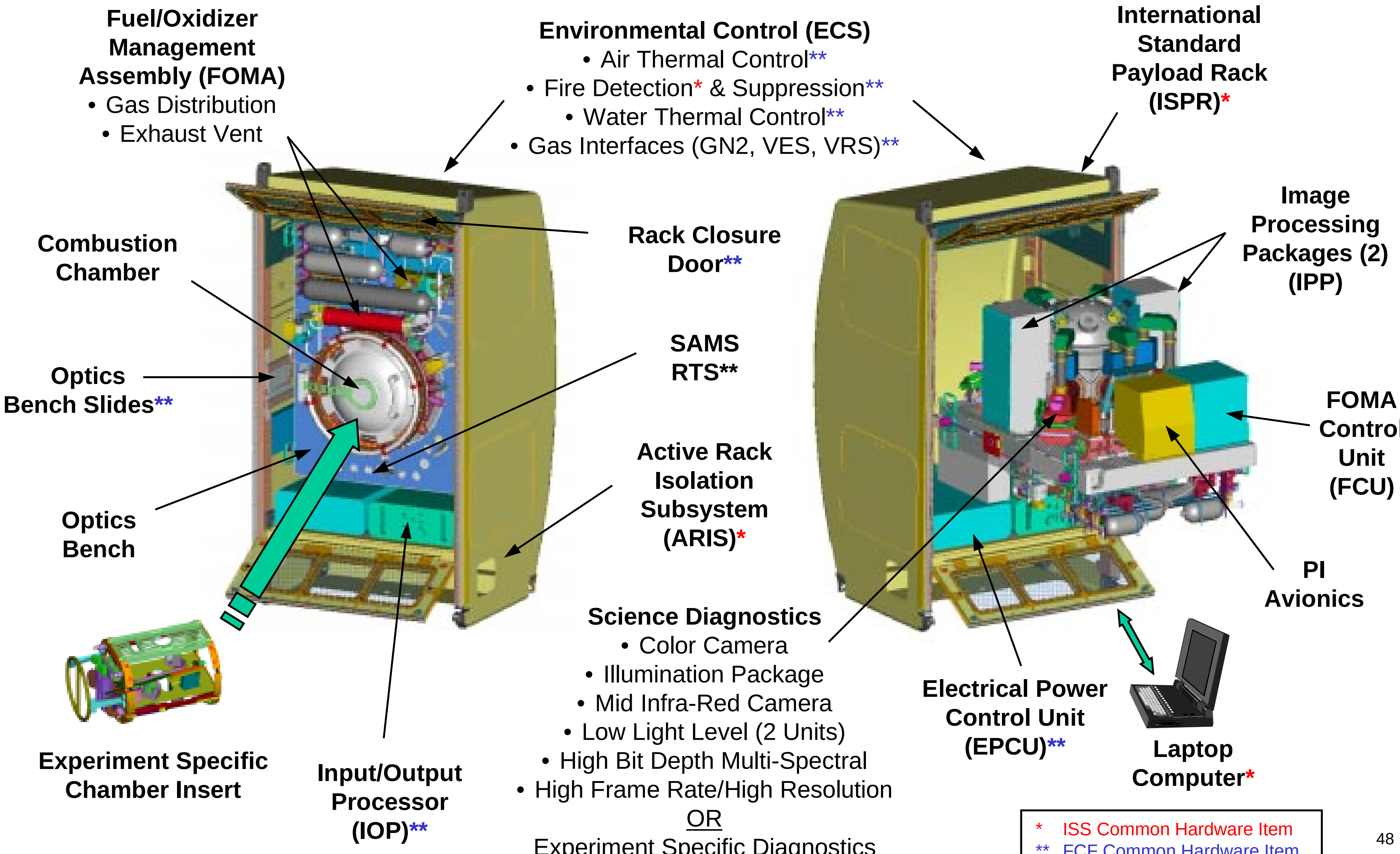
Launch Date	Flight	Delivered Elements
20-Nov-98	1A/R	FGB (Launched on PROTON launcher)
3-Dec-98	2A	Node 1 (1 Stowage rack), PMA1, PMA2, 2 APFRs (on Sidewalls)
13-May-99	2A.1	Spacehab Double Cargo Module, OTD (on Sidewall), RS Cargo Crane
17-Jul-99	1R	Service Module (Launched on PROTON launcher)
1-Aug-99	1P	Progress M1
5-Aug-99	2A.2	Spacehab Double Cargo Module
14-Oct-99	2P	Progress M1
28-Oct-99	3A	Z1 truss, CMGs, Ku-band, S-band Equip, PMA3, EVAS (SLP), 2 Z1 DDCUs (Sidewall)
2-Dec-99	4A	P6, PV Array (6 battery sets) / EEATCS radiators, S-band Equipment
10-Jan-00	2R	Soyuz - TM - (a) - 3 Person Permanent International Human Presence Capability
3-Feb-00	5A	Lab (5 Lab System racks), PDGF (on Sidewall)
15-Feb-00	3P	Progress M
16-Mar-00	5A.1	Lab Outfitting (Sys racks, RSRs), (on MPLM)
10-Apr-00	4P	Progress M1
20-Apr-00	6A	Lab Outfitting (Payload Racks, RSPs, RSRs) (on MPLM), UHF, SSRMS (on SLP) - (b) - Microgravity Capability
30-Jun-00	2S	Soyuz - TMA
13-Jul-00	7A	Airlock, HP gas (2 O2, 2 N2) (on SLDP)
Phase 2 Complete		* - Sequence and schedule after Flight 7A are under review.
16-Jul-00	5P*	Progress M
10-Aug-00	4R*	Docking Compartment 1 (DC1), RS Cargo Crane
24-Aug-00	7A.1*	4 RSRs, 6 RSPs, ISPRs (on MPLM), OTD, APFR (on Sidewall)
4-Sep-00	6P*	Progress M1
23-Oct-00	7P*	Progress M1
9-Nov-00	UF1*	ISPRs, 2 RSRs, 2-RSP-2s (on MPLM), Spares Warehouse
10-Dec-00	8P*	Progress M1
18-Dec-00	3S*	Soyuz - TM
12-Jan-01	8A*	S0, MT, GPS, Umbilicals, A/L Spur
15-Mar-01	UF2*	ISPRs, 3 RSRs, 1 RSPs, 1 RSP-2s, MELFI (MPLM), MBS, PDGF (Sidewalls)
3-May-01	9A*	S1 (3 rads), TCS, CETA (1), S-band
12-Jul-01	9A.1*	Science Power Platform w/4 solar arrays and ERA
16-Aug-01	11A*	P1 (3 rads), TCS, CETA (1), UHF
TBS	3R*	Universal Docking Module (UDM)
20-Sep-01	12A*	P3/4, PV Array (4 battery sets), 2 ULCAS
TBS	5R*	Docking Compartment 2 (DC2)
6-Dec-01	12A.1*	ISPR, 3 RSRs, 1-RSP-2s, 1 RSP-1 (MPLM), P5, Radiator OSE
24-Jan-02	13A*	S3/4, PV Array (4 battery sets), 4 PAS
4-Apr-02	10A*	Node 2 (4 DDCU racks), NTA (on Sidewall)
16-May-02	10A.1*	Propulsion Module
25-Jul-02	1J/A*	ELM PS (4 Sys, 3 ISPRs, 1 Stow), 2 SPP SA w/ truss, [illegible] ields
4-Sep-02	1J*	JEM PM (4 JEM Sys racks), JEM RMS
TBS	9R*	Docking & Stowage Module (DSM) (FGB [illegible] type)
17-Oct-02	UF3*	ISPRs, 1 JEM rack, 1 RSP, 1 RSP-2 (on [illegible] 1 Ex[illegible] Pallet w/ PL
14-Nov-02	UF4*	Truss Attach Site P/L, Express Pallet w/ P[illegible]loads, ATA, SPDM (SLP)
14-Feb-03	2J/A*	JEM EF, ELM-ES w/ Payloads, 4 PV battery sets (on Spacelab Pallet)
13-Mar-03	14A*	2 SPP SA w/ truss, 4 SM MMOD Wings (ULC), Cupola (SLP), Port Rails (ULC)
TBS	8R*	Research Module #1 (RM-1)
6-Jun-03	UF5*	ISPRs, 1 RSP, 1 RSP-2 (on MPLM), Express Pallet w/ Payloads
10-Jul-03	20A*	Node 3 (2 Avionics, 2 ECLSS racks)
TBS	10R*	Research Module #2 (RM-2)
25-Sep-03	17A*	1 Lab Sys, 4 Node 3 Sys, 3 CHeCS, 2 RSP-2s, ISPRs (MPLM) - (c) - 6 Person USOS ECLSS Capability
30-Oct-03	1E*	APM (5 ISPRs)
4-Dec-03	18A*	CRV #1, CRV adapter - (d) - 6 Person Permanent International Human Presence Capability
29-Jan-04	19A*	5 RSP-2, 1 RSR, ISPRs, 4 Crew Qtrs. (on MPLM), S5 - (e) - Rack traffic assumes transition to 6 person crew on 19A.
4-Mar-04	15A*	S6, PV Array (4 battery sets), Stbd MT/CETA rails
1-Apr-04	UF6*	3 RSP-2s, 1 RSP, ISPRs (on MPLM), 2 PV battery sets (on SLP)
20-May-04	UF7*	Centrifuge Accommodations Module (CAM), ISPRs (TBD)
1-Jul-04	16A*	Hab (6 Hab sys racks, 2 RSRs, ISPRs) - (f) - 7 person permanent crew capability



CIR Project Organization



CIR Elements / Subsystems



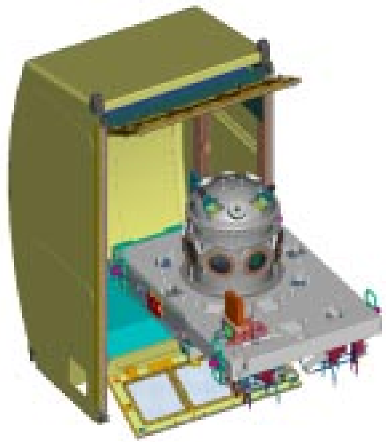
* ISS Common Hardware Item

** FCF Common Hardware Item

CIR Launch & Operating Configurations

Launch Configuration

Optics Bench Front View
(Doors closed & secured for launch)

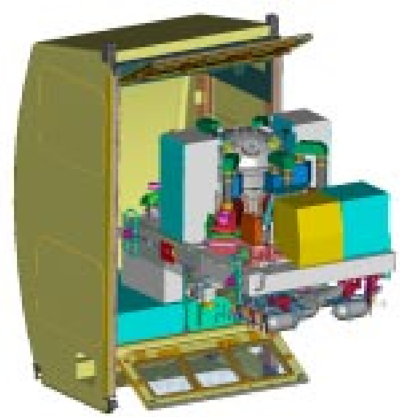


Optics Bench
Rear View

- **Elements of CIR are Stowed for Launch in Foam Lined Resupply Lockers in Order to;**
  - Decrease mass to meet the integrated rack mass limitation of 804 kg for launch in the MPLM.
  - Increase the natural frequency of the rack for launch
  - Minimize environmental testing of packages which reduces development costs and enables use of COTS components.

- **CIR Stowed Items for Launch Include;**
  - Diagnostics Packages
  - Image Processing Packages
  - Experiment specific chamber insert & PI avionics
  - FOMA gas bottles and filter cartridges
  - Rack/Station interface umbilical set
  - Some ARIS components

Operating Configuration



CIR Diagnostics and
Image Processing Packages
Installed by Crew On-Orbit

CIR Gas Bottles, Filters and
Experiment Specific Hardware
Installed by Crew On-orbit

CIR Primary Orbital Replacement Units (ORU)**

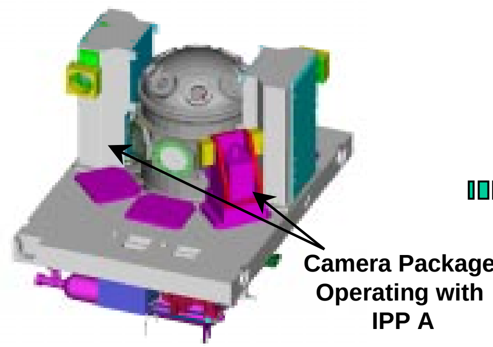
- **Science Diagnostics**
  - •HFR/HR, HiBM, LLL, Color, Mid-IR Cameras
  - •Illumination Package
- **Avionics Packages**
  - •Image Processing Packages
  - •FOMA Control Unit
  - •Input/Output Processor
- **FOMA Components**
  - •Gas Bottles
  - •Adsorber Cartridges
- **Experiment Provided Hardware**
  - •Chamber Insert
  - •PI Specific Diagnostics Packages
  - •PI Specific Avionics

** Primary ORUs are changed out routinely to support different experiments. Other items in the CIR are ORU to facilitate on-orbit maintenance and/or change-out of limited life items.

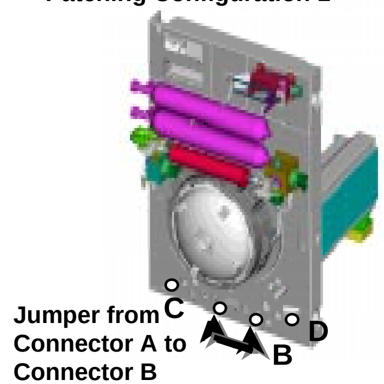
CIR Operations - Reconfiguration

- The current CIR Design is the response to the following requirements/constraints
  - Minimize the use of crew time
  - Minimize upmass and volume
  - Maximize the flexibility for science
  - Provide for a high degree of maintainability
- This design accomplishes these goals by; allowing a high degree of ground control for the execution of science thereby reducing crew time required.
- Providing a suite of diagnostics which reduces the amount of equipment that an investigator is required to supply (reduces upmass and volume) while simultaneously providing the capability to run multiple experiments.
- Easy access to and removal of ORUs facilitates maintenance

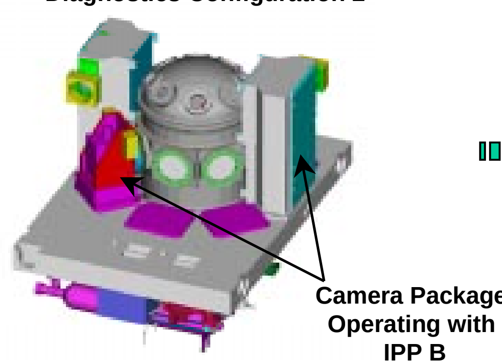
Diagnostics Configuration 1



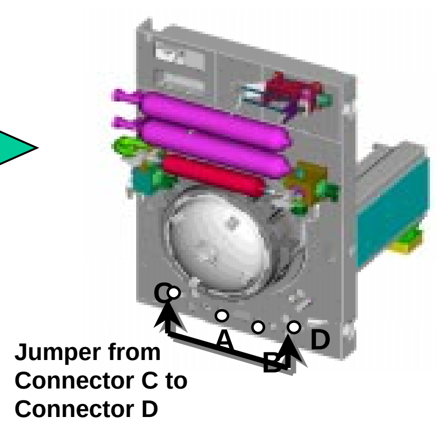
Front Panel Connectors Patching Configuration 1



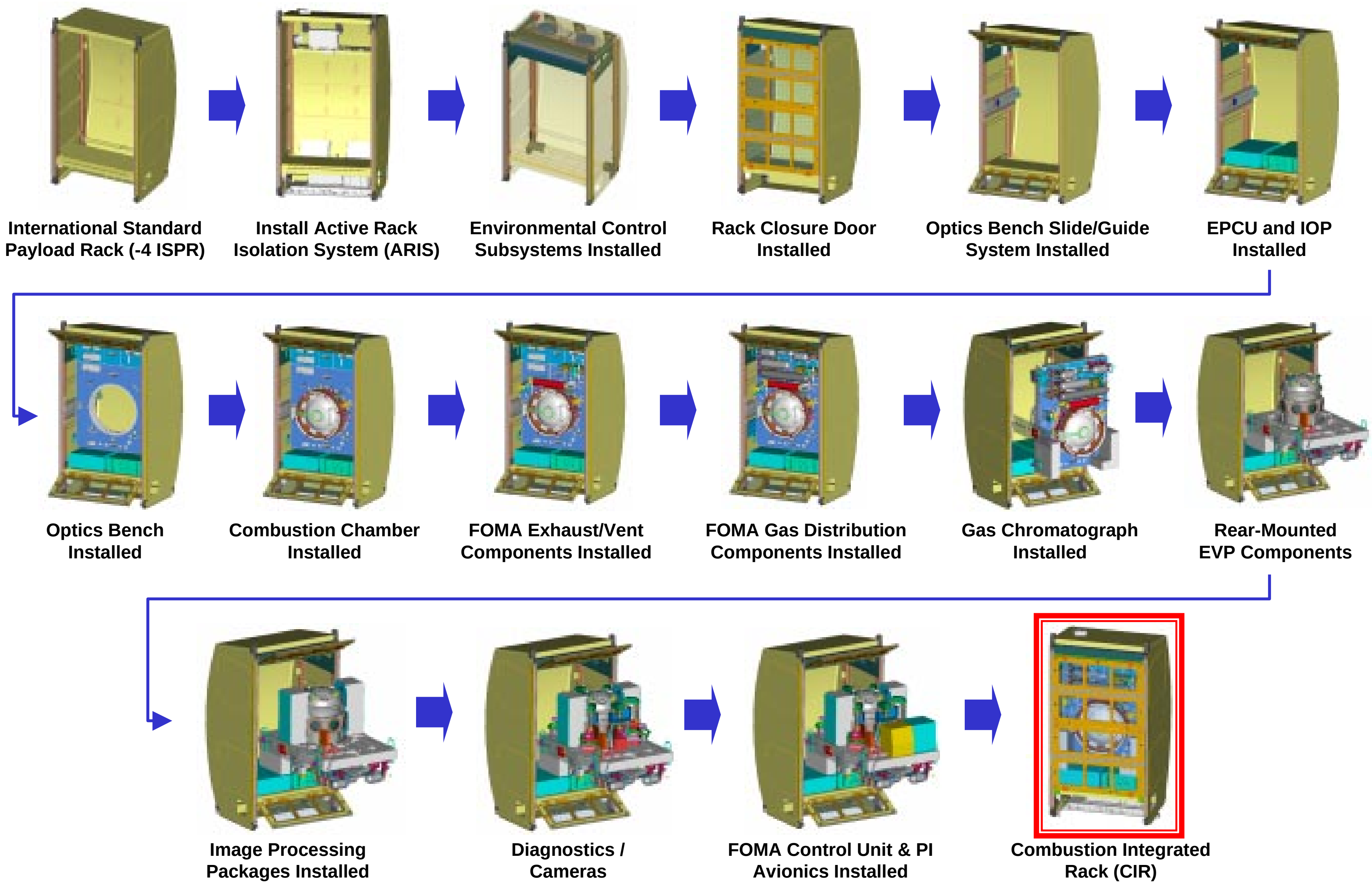
Diagnostics Configuration 2



Front Panel Connectors Patching Configuration 2



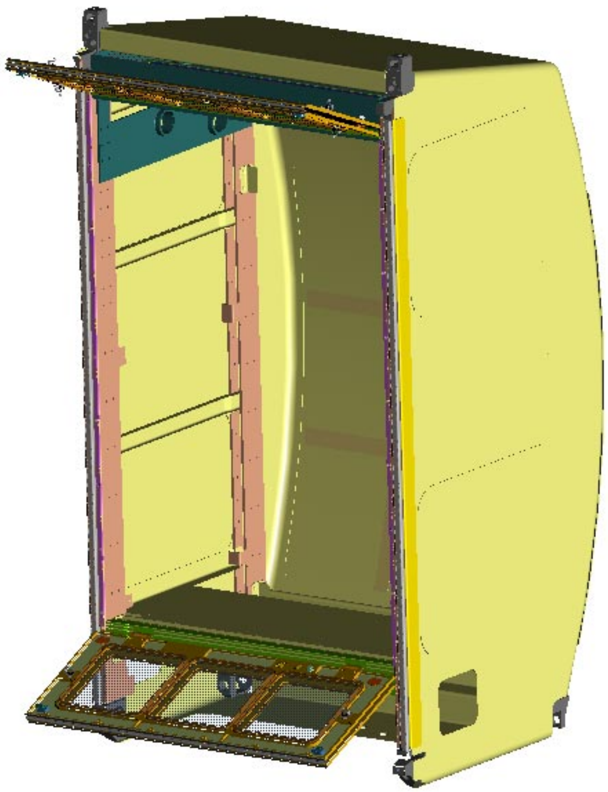
CIR Assembly Sequence



CIR Hardware Design

Malcolm Robbie
Dan Catalano
Rick Verbus

ISPR-4 RACK



Description

- The ISPR is Approx. 174,6 cm x 96.5cm x 72.5 cm
- Total usable volume 1.6 m3.
- Constructed from composite materials
- The CIR will use the rack in it's 4 post configuration
- Approx mass 110 kg.
- Approx mass carrying capacity 700 kg.

Stress Analysis

- Analysis conducted by Boeing/Huntsville and documented in D683- 56171-1
- All margins of safety (MS) positive under rack level loading
- Some small negative MS under component level loading
  - Component loads were very conservative due to large contribution from random vibration loads
  - ISS Program has promised relief in RV loads for components with weight greater than 100 lb.

Rack Normal Modes Analysis

- Frequency of one mode below 25 Hz. minimum
  - Coupled loads analysis will be performed by Boeing to assure design load factors are conservative
  - Structural augmentation approaches will be investigated
  - Impact on ARIS performance has been initiated

Optics Bench basics

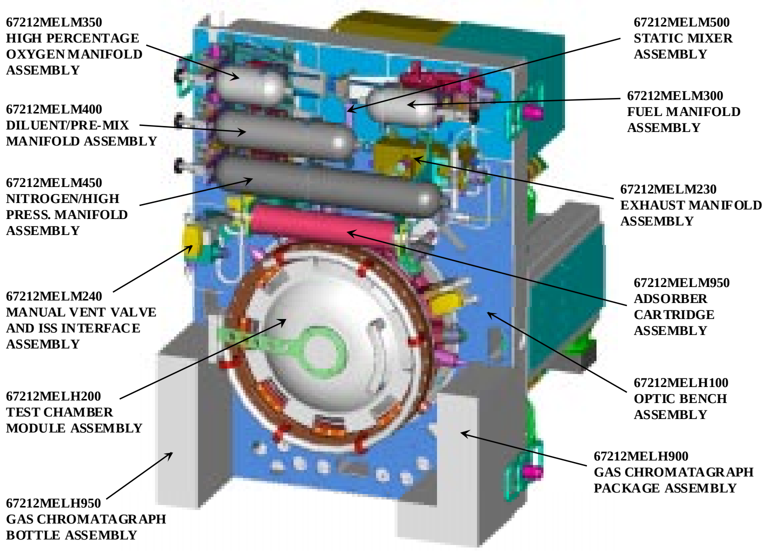
Description

- The optics bench provides for the structural mounting of all of the packages onto the front and rear surfaces.
- All harnessing is internal to the bench.
- The optics bench interfaces to the rack via a five pin connection to the rack.
- The bench folds out and down for easy access to the diagnostic assemblies.
- The diagnostics incorporate a quick latch device and universal mounting locations.
- No tools required for configuring an experiment.

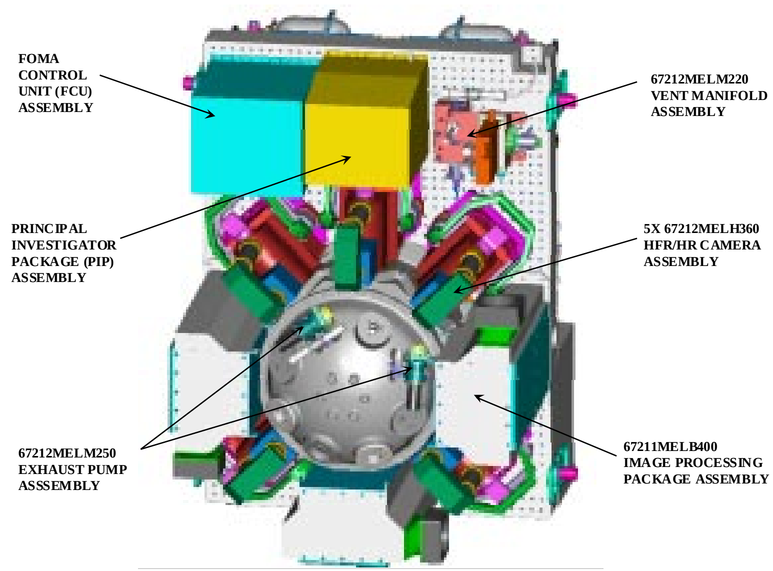
Specifications

- 90.2 cm x 124.5 cm x10cm thick
- Approx. mass 365kg. launch 563 kg. on orbit
- 9 universal mounting locations cooling capacities 450 & 225 watts.
- Material Aluminum 6061-t6

Front and Back Views of Optics Bench



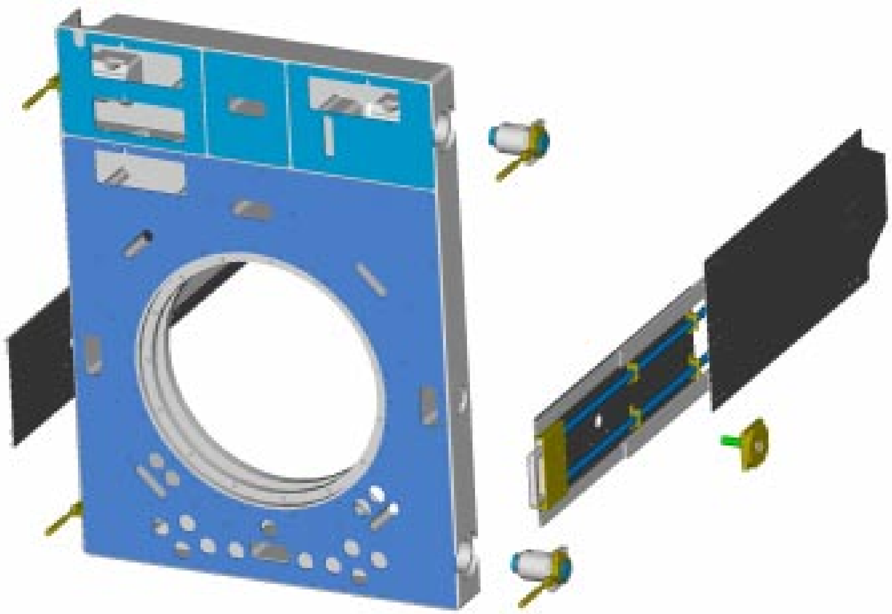
COMBUSTION OPTIC BENCH/FOMA ASSEMBLY (67212MELH100) FRONT VIEW



COMBUSTION OPTIC BENCH/FOMA ASSEMBLY (67212MELH100) REAR VIEW

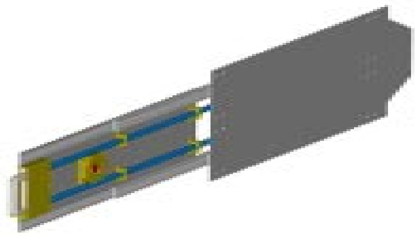
- Items that required the most crew access where positioned on the front of the optics bench. Namely fluid bottles, filters and chamber lids.
- The fluid elements and the lid where relatively flat in shape permitting the optics bench to mounted closest to the doors. This optimize the diagnostic volume in the back permitting longer optical paths (notice the diagnostic do not lie flat on the optics bench but protrude into the rack). This permitted the greatest number of different diagnostics and optimized there capabilities.
- Other considerations in design, minimize fluid lines and electrical feed thru’s on the optics bench.
- Chamber feed thru’s needed to be made in the front thereby further consolidating the fluid components to the front.

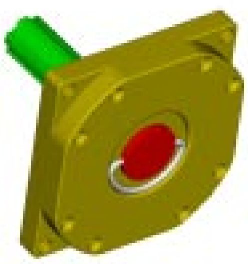
Experiment Bench Interface To The Rack



Description

- Basic operation of optics bench rollout
- Retract mounting pin at four corners
- Deploy slide handle, squeeze handle to release brake and extend out of the rack.
- Rotate D clip to release rotational brake and fold bench down.
- Reposition diagnostics and install PI specific box.
- Reverse process to reinstall into rack.
- Exploded view of optics bench to the rack showing optics bench, slides, retractable pin, ext. rotate device and rack





Mounting pin operation

- No tools operation
- Ease of use
- Common hardware throughout the facility
- The is pin operated by the rotation of a ratchet handle. The handle rotates an inner nut that is pinned to the shaft internally. The pin also engages the outer housing cam groove. When the nut rotates the pin is extended or retraced by the cam action.

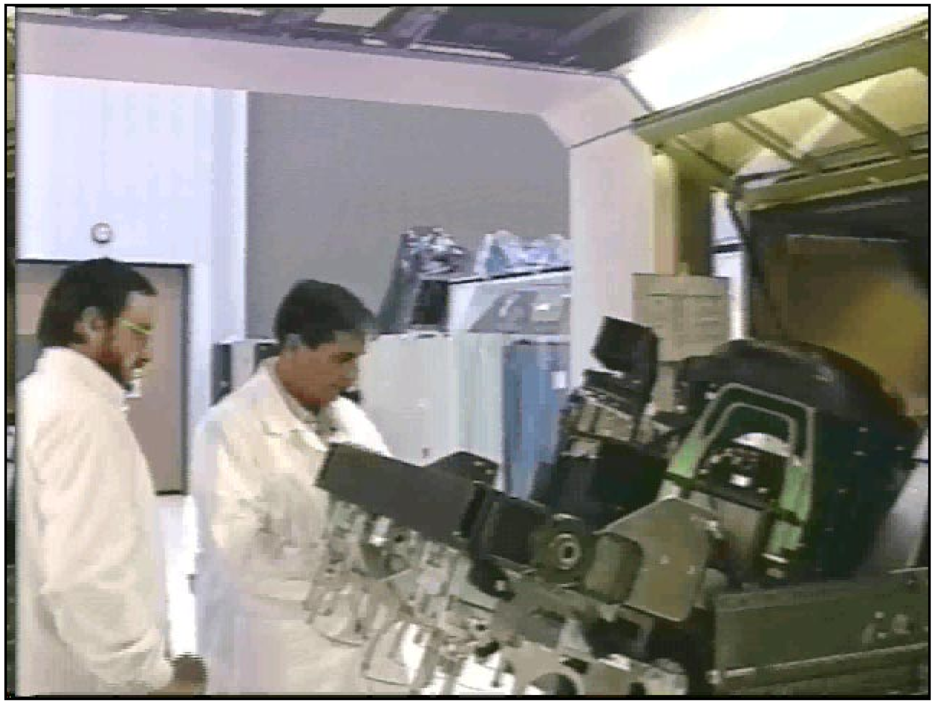
Extend retract device

- Simple no tools operation of linear brake assembly
- Harden steel components for long life
- Override capability
- Visual indicators for proper positioning and wear indicators
- Single hand operation from one side
- The brake assembly is simply a wound spring on a hardened shaft.when the handle releases the spring is unwound and clamps onto the shaft.

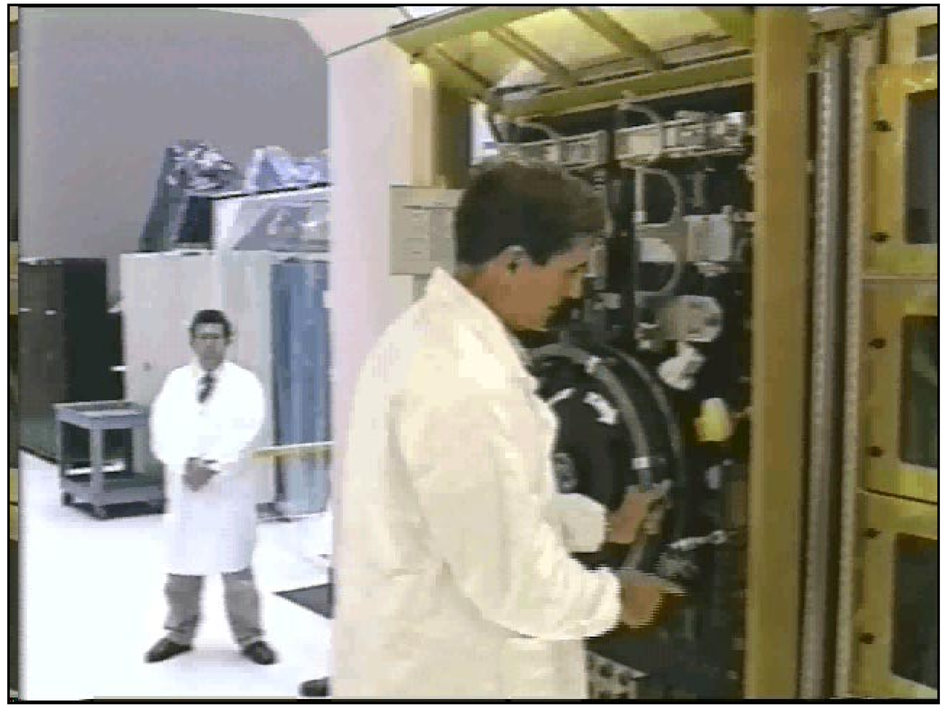
Rotational brake device

- Simple no tools operation of brake assembly
- Harden steel components for long life
- Override capability
- Visual indicators for proper positioning and wear indicators
- Single hand operation from one side
- The brake assembly operates by a spring loaded engagement of the brake drums into the brake housing. The brakes are disengaged by rotating a “D” clip linked to brake pads. This frees the assembly to rotate. Buy tuning the friction material and the spring force a balance between proper braking and override capabilities is achieved.

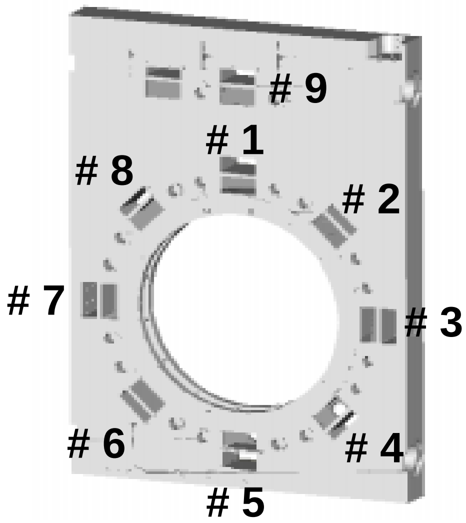
Space Station Fluids and Combustion Facility



RACK ROTATION



EXTEND RETRACT

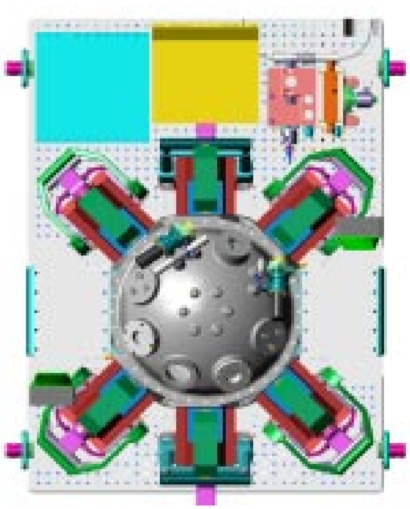


Universal Mounting Locations

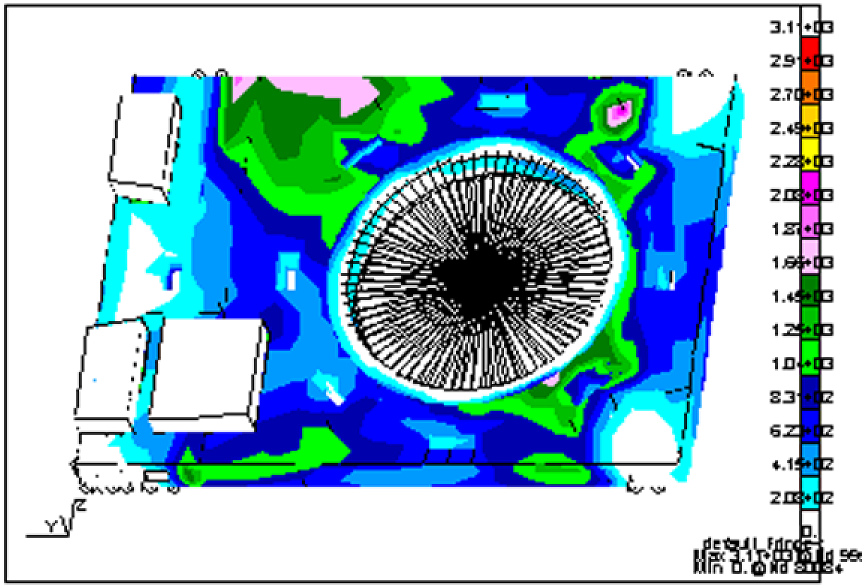
- Nine universal mounting locations are show around the perimeter of the back side of the optics plate.
- These standard locations provide common power, command/control and data connection. Air cooling, structural mounting and optical alignment is also achieved.
- Combined with a quick release latch this enables a rapid reconfiguration of the diagnostics and image processing packages.

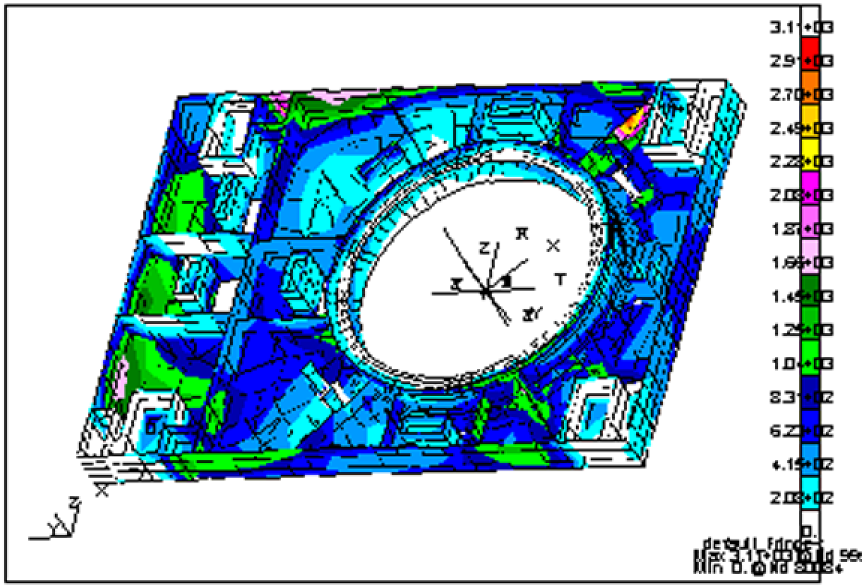
Typical ORU

- A typical ORU will consist of various diagnostic assemblies image processing packages and instrumentation.

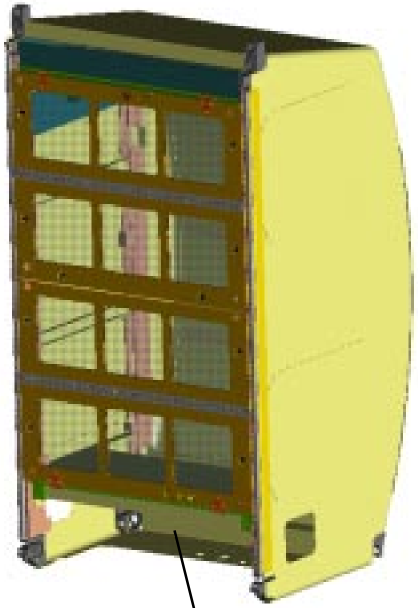


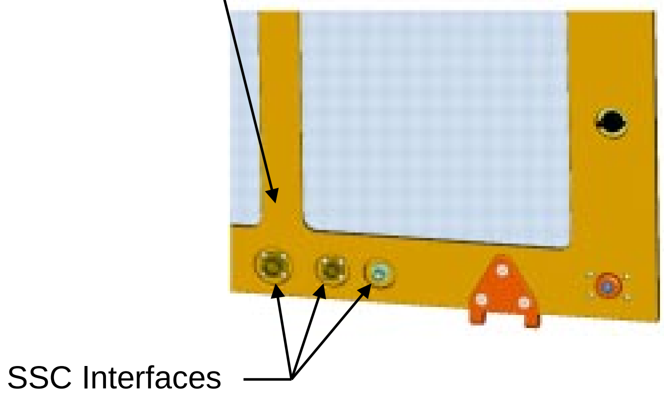
Stress Distribution Model





ISPR Rack Doors





Requirements

- SSP 57217 FCF CIR Hardware ICD
- SSP 57000 On-Orbit Temporary Protrusion

Description

- Used on all 3 FCF Racks (CIR, SAR and FIR)
- Rack seal for Air Thermal Control System
- Thermal containment and Acoustic attenuation
- Full or partial access to rack components
- No tools to open/close
- Station Support Computer interface in lower right panel
- Lexan windows for internal rack observation
- Fire Hole and Hand-Held Gas Sample port
- Designed for maintainability: Seals, windows

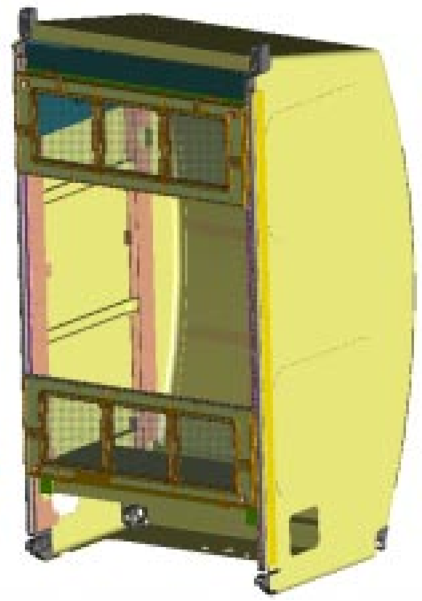
ISPR Rack Doors

Specifications/Features

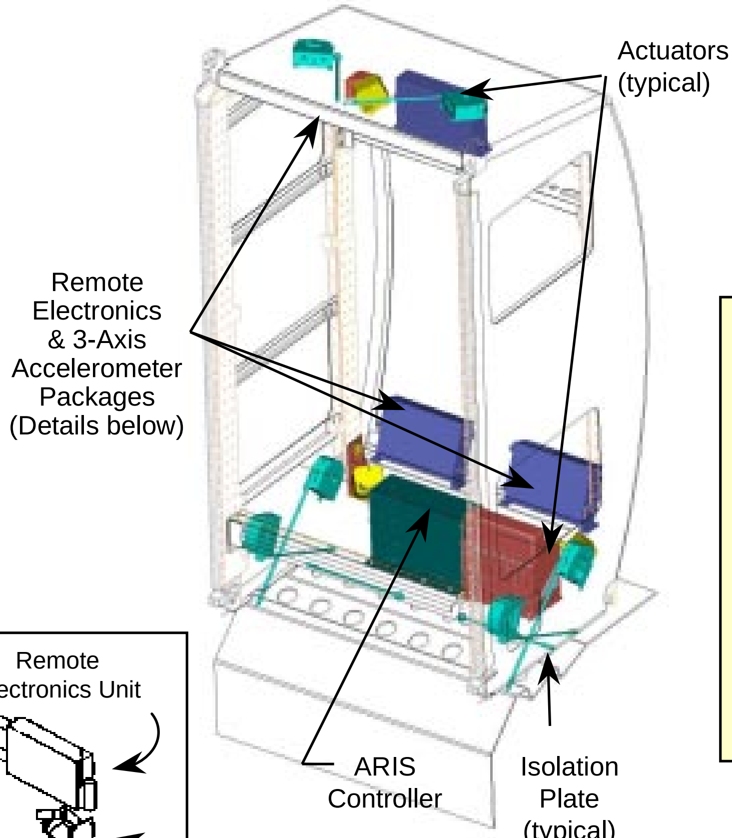
- 4 Door Panels, 11mm x 368mm x 986mm
- Material: Aluminum
- Windows: Lexan (could be blanks)
- Weight: Approximately 20 kg

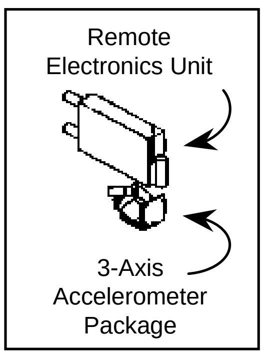
Development Status/Test Results

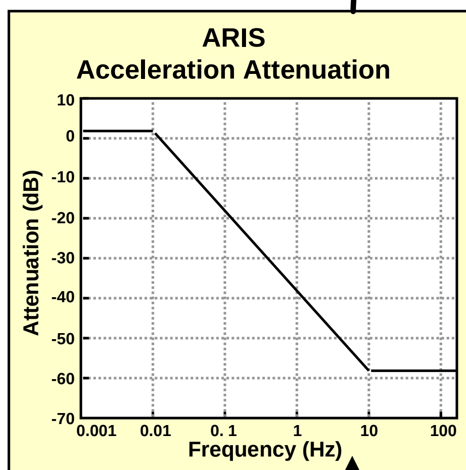
- Evaluated in Crew Review 11/98
- EM Design incorporates attachment methods to composite rack

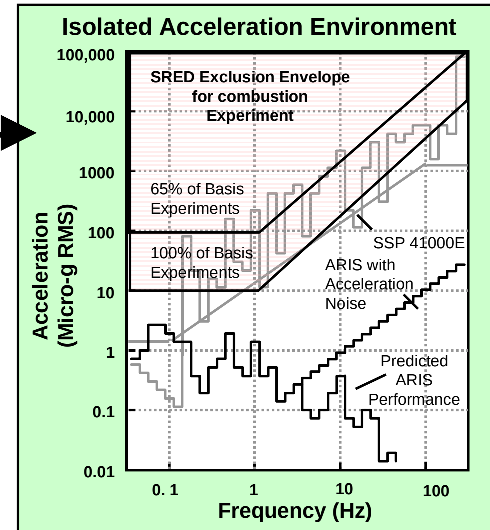


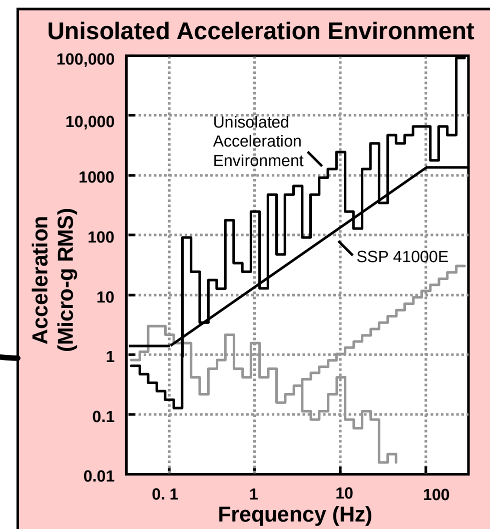
FCF Combustion Integrated Rack -- Vibration Isolation





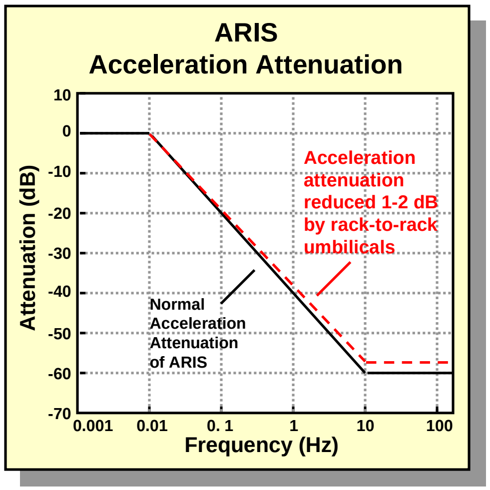


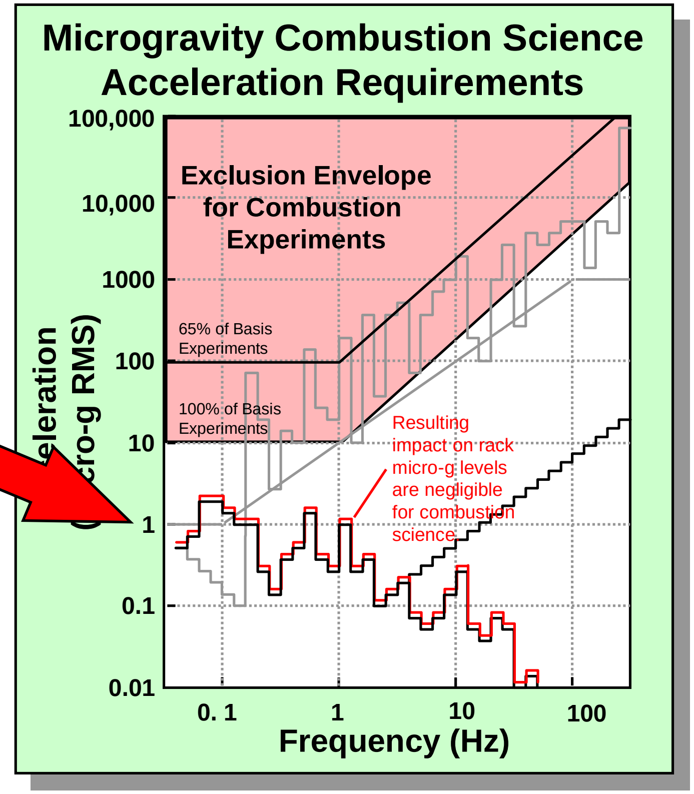




*The **Active Rack Isolation Subsystem (ARIS)** provides rack-level attenuation of on-orbit low frequency/low amplitude mechanical vibrations transmitted from the US Lab to each facility rack when science operations are conducted.*

Effect of Laptop Umbilical on Acceleration Environment





Laptop Computer Example:

- Rack-to-rack umbilical configuration assumed by Boeing was an Ethernet cable (4 wire bundle of 22 AWG wire) plus power cable (3 wire bundle of 16 AWG) running cross rack for computer.
- Active isolation performance impact reported by Boeing due to added umbilical was a 1-2 dB reduction in acceleration attenuation at frequencies above 1 Hz (assuming umbilicals were properly designed).
- Resulting change in rack Micro-g environment (est. by FCF) is that instead of ARIS providing ~1.0 micro-g at 1 Hz, ARIS will provide ~1.25 micro-g at 1 Hz. In this case, there would would not be an impact to combustion science.

ROM estimate done by FCF indicates that combustion science would not be impacted by rack-to-rack umbilicals until ARIS acceleration attenuation is reduced ~15-20 dB due to added stiffness of cabling.

CIR Combustion Chamber

Requirement

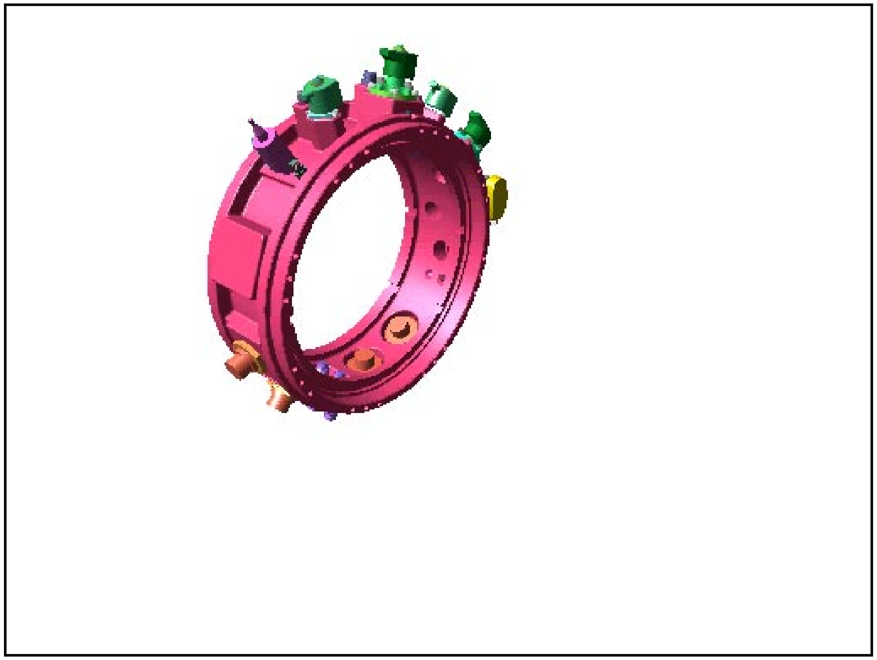
- The combustion chamber shall accommodate the basis experiment's test sections and provide pressure containment for initial gas pressures of 0.02-3 atmospheres and a pressure increase of 9 atmospheres absolute.

Description

- Containment for multiple combustion experiments. Contains ports for GC sampling, vacuum venting, water cooling, data, power, and thermocouple feed-throughs, plus ports for oxygen, diluent, and fuels.

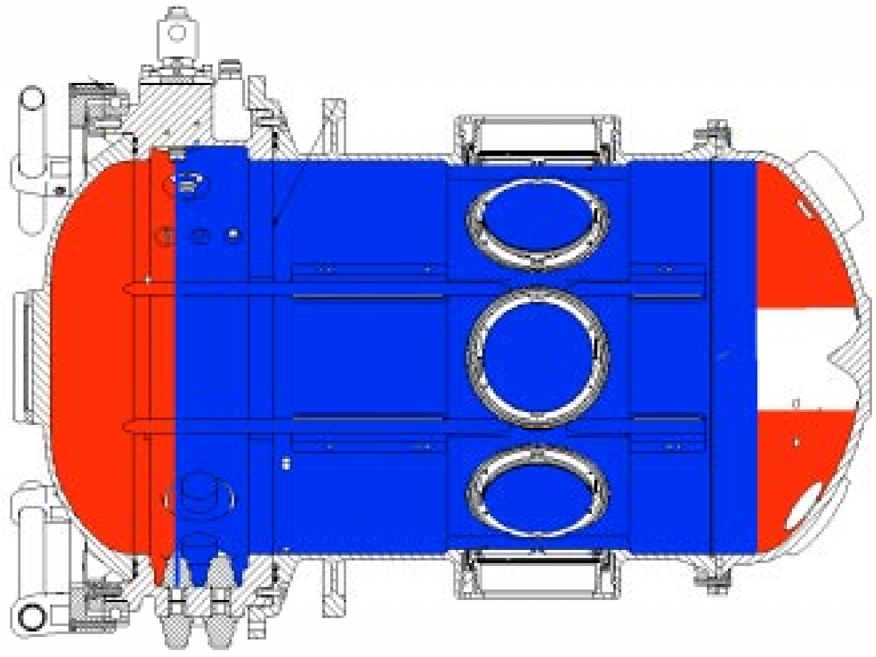
Specifications/features

- Material: 7075-T73 aluminum
- Minimum internal free volume: 101 liters of free volume.
- Composed of five major sections:
  - Rear end cap
  - Window Section
  - Interface Resource Ring (IRR)
  - Front end cap
  - Breech lock mechanism



Chamber Assembly Animation

CIR Combustion Chamber



Cross section of Chamber with usable areas color coded.

- Maximum Design Pressure (MDP) is 135 psia.
- Eight 115 mm diameter field of view replaceable windows allowing for three simultaneous orthogonal views.
- Weight: Approximately 131 kg.
- Designed to require as few tools as possible for operation and maintenance.
- Accepts a Chamber Insert Assembly (CIA) with maximum dimensions of 600 mm long, and 396 mm in diameter. The maximum test section dimensions of the basis experiments along the axis, width and height are 450, 300 and 180 mm respectively.
- The blue area in the figure to the right indicates the region into which a CIA could be placed.
- Areas in red indicates areas that may be used but require consultation with FCF.
- White areas indicate locations of known permanent protrusions into the chamber volume.
- The CIA to chamber interface consists of four rails positioned 22.5° above and below the horizontal axis of the chamber. This allows the CIA to utilize all eight windows.

CIR Combustion Chamber

Outside View of the Rear Endcap

- Rear end cap utilizes two, 1/4” cross section o-rings to make the seal between it and the window section. Two seals required by phase 0/1 safety review board.
- 13 bosses located on the rear end cap, 5 large and 8 small.
- 8 small bosses are used to mount the pumps utilized in the FOMA filter loop, four bosses to each pump.
- Two large bosses each are machined for a temperature thermister, a pressure transducer, and a pressure switch.
- One large boss will be used for the fan power feed-through and another for the FOMA filtration loop return valve.
- A protrusion is located on the inside to redirect the air flow from the fan that is attached to the inside of the rear end cap.

CIR Combustion Chamber

Window Section

- The window section has eight locations for replaceable windows.
- Each location has a stainless steel insert to eliminate wear on the aluminum window section.
- The window insert contains two 1/4” cross section O-rings to seal at each end which were driven by the phase 0/1 safety review.
- The window section has recessed areas 22.5° above and below the horizontal of the chamber and on either side of the vertical to accommodate a CIA alignment system.
- The recesses have bosses on the outside of the chamber to attach the alignment system.
- Four slotted holes on the chamber wall locate the CIA with respect to the windows.

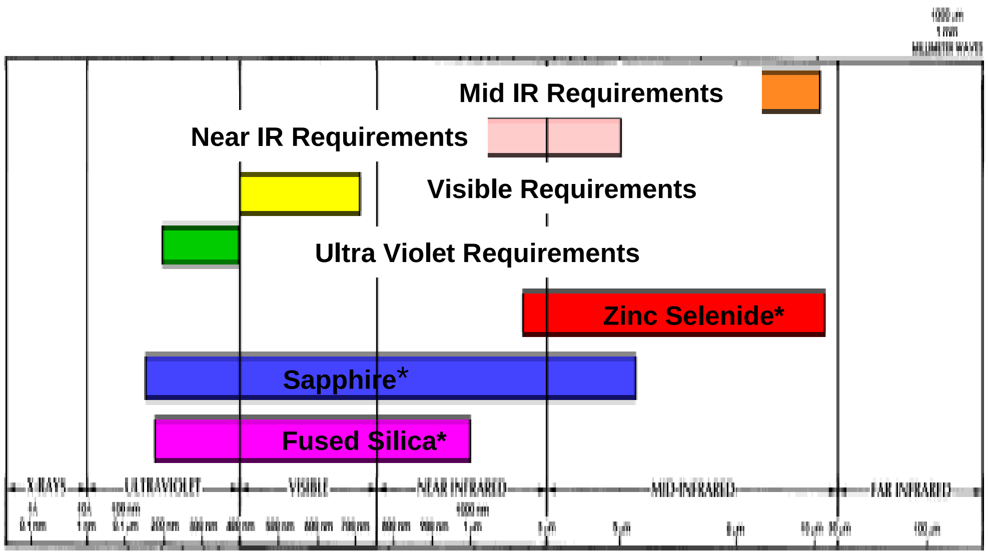
CIR Combustion Chamber

Breadboard Replaceable Window

- The Replaceable Window uses a triple lead ACME screw to screw into the stainless steel insert.
- The window holder seals against the stainless insert using two o-ring seals as requested by the phase 0/1 review panel.
- The window material seals using an o-ring seal and a gasket seal. The window material is held in place using a soft durometer elastomeric.
- The ratcheting action of the window is achieved by a serrated profile on top of the ACME screw. A dimple plate is placed on top of the screw, a wave spring is placed on top of the plate, which is in turn held captive by a spring capture ring. This assembly is held in place by another span ring.
- The tool-less function of the windows is achieved utilizing two D-handles that rotate out to allow installation/removal.
- Insertion of window is facilitated by a smooth ramp into the insert in response to a concern on the alignment raised during the crew review.

CIR Combustion Chamber

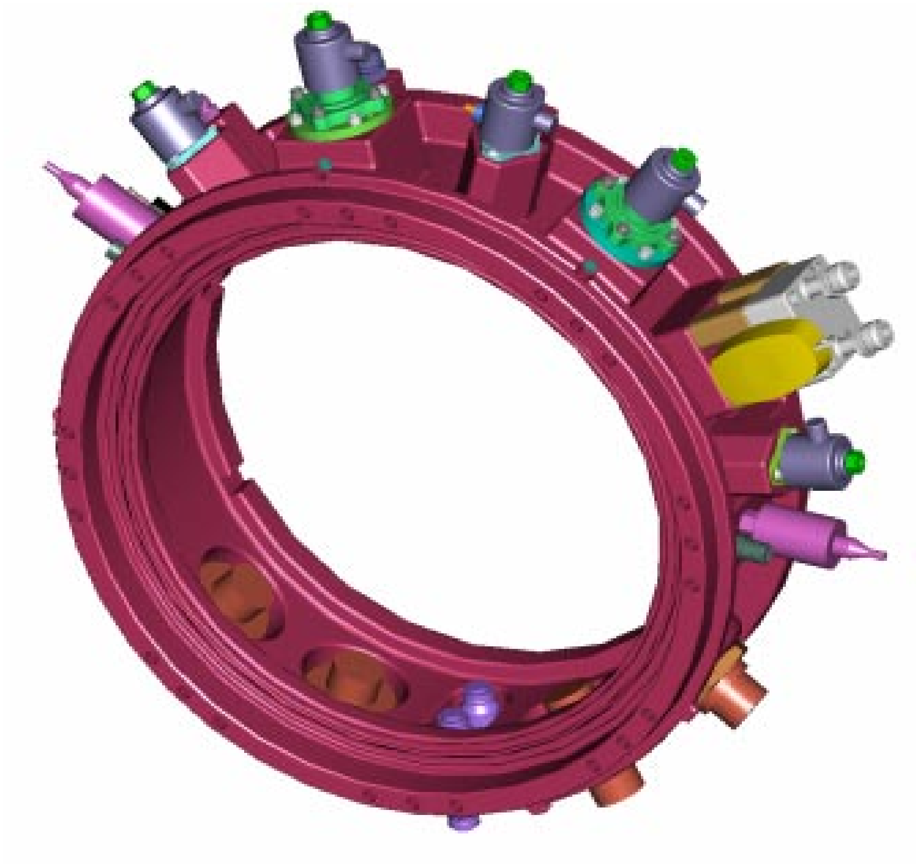
- The baseline window material is fused silica (SiO_2).
- Fused silica's transmission range will not support IR imagery.
- Infrared (IR) wavelength transmission requirements are in two ranges:
  - 1 to 5 microns
  - 8 to 12 microns
- Sapphire (Al_2O_3) is desired (transmission range .17 to 5.5 microns) but no fracture properties are available for use in the FLAGRO fracture analysis program.
- JSC safety will not approve window material without a FLAGRO analysis.
- No sources for fracture properties on any IR materials have been discovered.
- Selection of sapphire would still require a material for the 8 to 12 micron range but would reduce the need to change out the windows for the lower range.
- Material presently under investigation for the mid Infrared range is Zinc Selenide.
- Determination of fracture properties will require significant test program, however if the test program is not performed no experiment requiring IR camera data can be performed.



Wavelength

*** NOTE: Wavelengths shown are based on maximum transmission range listed in available documentation.**

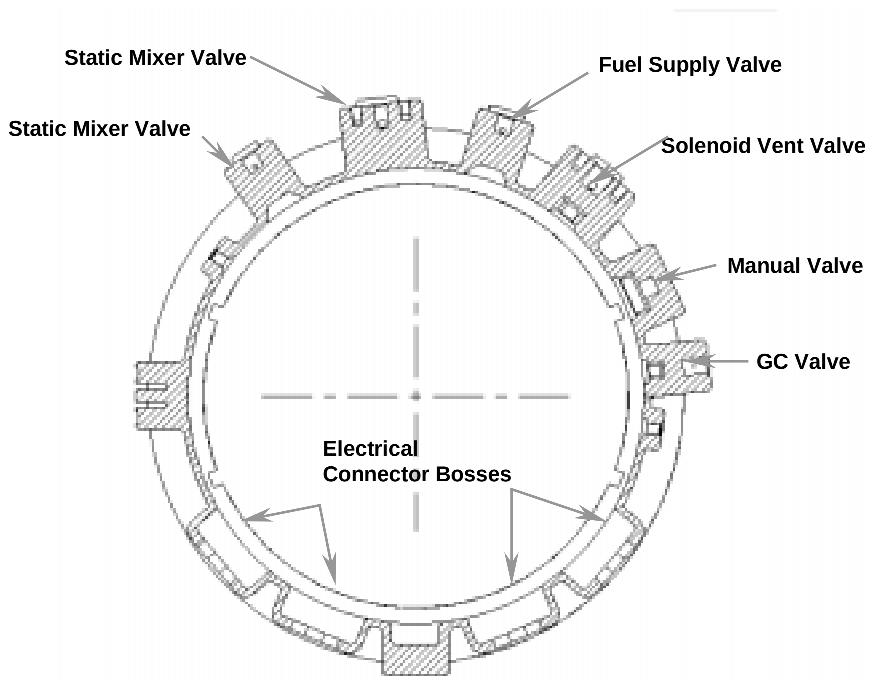
CIR Combustion Chamber



Interface Resource Ring

- The IRR is 284 mm at its maximum distance from its center and 175.5 mm long. The minimum internal diameter is 410 mm diameter and the maximum internal diameter is 440 mm.
- The minimum wall thickness is 6.5 mm.
- Notches are cut in the minor diameters to allow the CIA to chamber interface. This interface is allowed to extend over the IRR to protect the electrical connections and instrumentation.
- The IRR has 40, M8 keenserts for attachment of the Window Section.
- A shelf is on the front end of the IRR is for the Kaydon bearing. Two protrusions located on this shelf act as hard stops to limit the breech lock rotation to 23°.
- Three holes located between the protrusions are used by pins on the Kaydon bearing to lock it in the open and closed position and to safe it in case of accidental opening of the chamber under pressure

CIR Combustion Chamber



Cross Section of IRR

- The IRR has a large boss to which are attached the rails for the linear translation stage of the front end cap hinge at the 9 o'clock position.
- It has a boss at the 6 o'clock position in which the water inlet and outlet quick disconnects are installed.
- Bosses are located at the 3 o'clock and 10 o'clock positions to allow for the installation of a pressure transducer and thermistor in each.
- Four bosses are located on the lower half of the IRR, two on either side of the water inlet/outlet. These bosses will be used to mount four feed-throughs for electrical connectors.
- Bosses are clockwise from the 3 o'clock position for:

  ¼" GC valve

  Manual vent valve

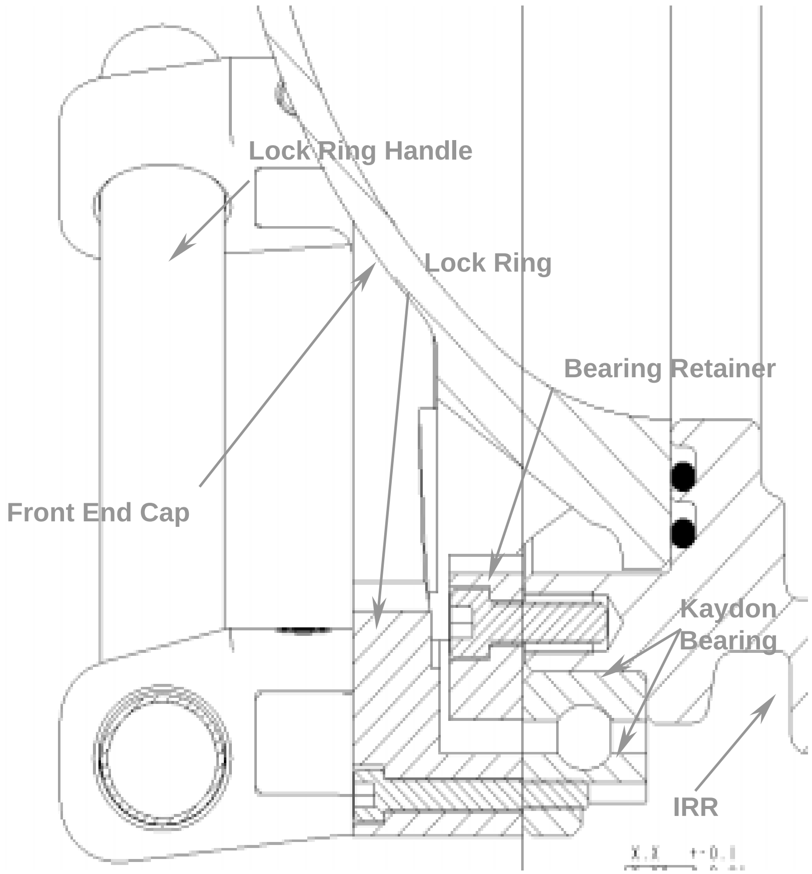
  ½" Automatic Vent valve

  ¼" Fuel supply valve

  ½" Static mixer valve

  ¼" High press. supply valve

CIR Combustion Chamber



Cross section of the breech lock mechanism

- The breech lock mechanism is composed of five major parts:
  - Bearing
  - Bearing Retainer
  - Locking Ring
  - Locking Ring Handle
  - Door Hinge
- All five parts work to allow the front end cap to seal and unseal without having to having to use tools or having to tether any part of the chamber assembly.
- The door hinge allows the door to be opened without having to stow it.
- The door rotation will make it protrude into the aisle by approximately 19 inches.
- Large lock ring handle was utilized extensively in the crew review to stabilize the crew member during operations performed inside the chamber.

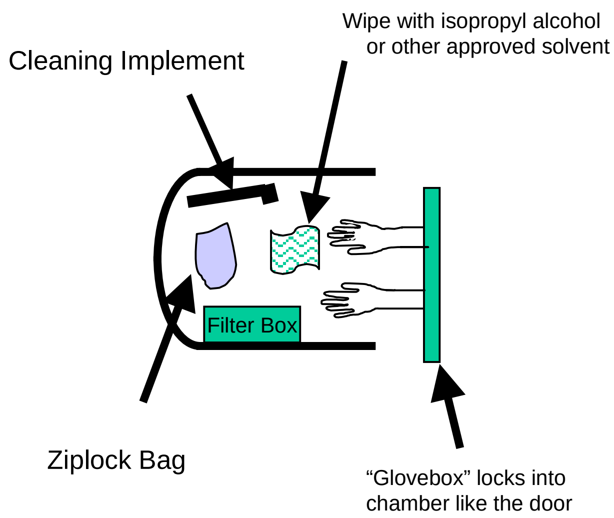
CIR Combustion Chamber

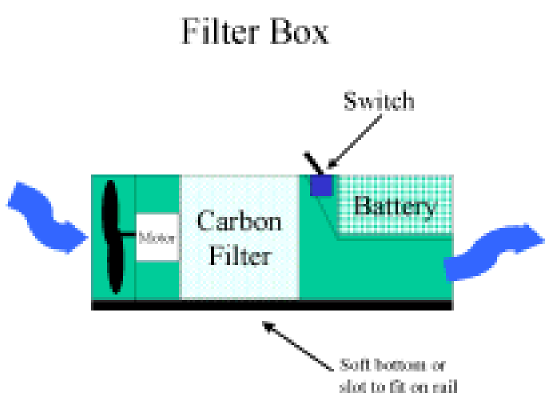
Video of Crew Review

Development Status/Test Results

- Windows and breech lock mechanism evaluated in Evaluated in Crew Review 11/98.
- Pressure test on preliminary breech lock design was successful.
- Engineering model windows has been updated to incorporated dual seal design and eliminate metal to glass contact as mandated by the phase 0/1 safety review.
- All interface points in the chamber have been updated to reflect the dual seal.

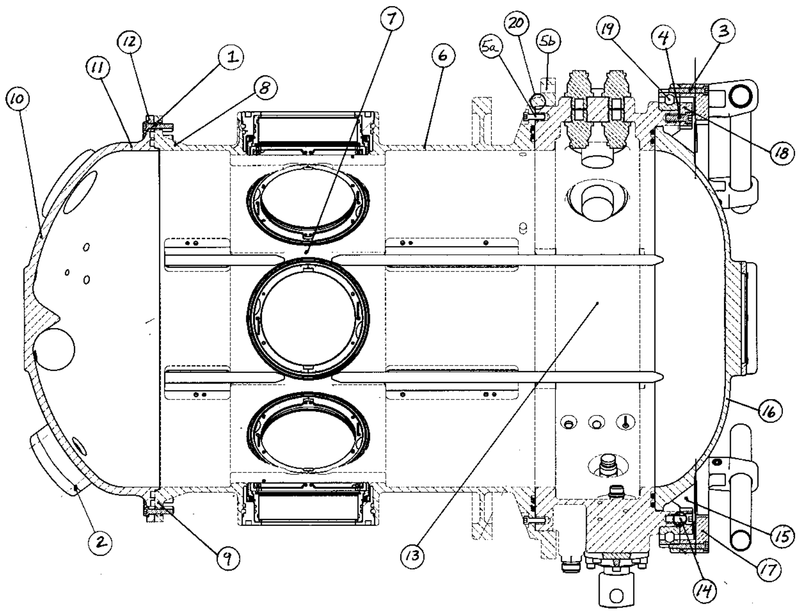
CIR Combustion Chamber





- Chamber cleaning will be performed to improve the environment available in the combustion chamber. Primarily to remove particles.
- The preliminary concept for cleaning the chamber is to turn it into a glovebox so that the aromatic solvents will be isolated from the crew member.
- The gloves would be attached to the chamber using the breech lock mechanism.
- Typical fluids that will be used for cleaning, due to the composition of the soot particles are:
  - Heptane
  - Pentane
  - Isopropyl Alcohol
  - Acetone (compatibility issue with Viton)
- Cleaning materials such as isopropyl alcohol impregnated wipes, ziplock bags to store used wipes in, and a cleaning implement that would be used to scrub hard to reach or stubborn areas.
- A self contained filter box would also be placed inside the chamber and used to absorb the fumes created by the wipes.

CIR Combustion Chamber



- Chamber analysis was performed using the pressure vessel code.
- All components analyzed have positive margins except for high contact stresses in the IRR, the front end cap tab, and the bearing retainer. (Contact stresses are due to modeling techniques used and are not present in reality)
- Preliminary analysis of fused silica windows shows positive margins.
- All fasteners have positive margins

CHAMBER MARGINS OF SAFETY

Location	Fasteners	M.S.(yield) (S.F.=1.5)	M.S. (ult) (S.F.=2.0)	Failure criteria/mode
1	Rear end-cap (bolt flange)	0.049	0.53	tension/shear
	Insert tear-out		large	tear-out of parent mat'l
2	Rear end-cap (boss)	0.19	0.82	" "
	Insert tear-out		large	" "
3	Lockring/bearing(thru bolt)	0.03	0.59	" "
4	IRR/retainer	0.09	0.6	" "
	Insert tear-out		large	" "
5a	Cyl.sec/IRR	0.018	0.61	" "
	Insert tear-out		large	" "
5b	Cyl.sec/Optic plate	0.21	0.84	
	Insert tear-out		large	" "
	Main Chamber			
6	Cylindrical section (away from flange,windows)	large	large	Max shear
7	Cylindrical section (between windows)	large	large	Max shear
8	Cylindrical section (near flange)	large	large	Max shear
9	Cylindrical section (flange)	large	large	VonMises(bending)
10	Rear end-cap (away from flange)	large	large	Max shear
11	Rear end-cap (near flange)	2.75	2.43	Max shear
12	Rear end-cap (flange)	1.029	0.85	VonMises (bending)
13	IRR (basic shell)	large	2.96	Max shear
14	IRR (I/F b/t retainer)	-0.237* (2.3)	-0.3*(2)	Contact stress (localized)
20	Cylindrical sec/IRR (I/F flange)	-0.04 **	-0.12 **	flange bending
	Breech Area ***			
15	End-cap (tab)	-0.6 (1.24)*	-0.64 (1.05)*	Contact stress (localized)
16	End-cap (dome area)	1.24	1.05	Max shear
17	Lock-ring	0.24	0.13	Max shear
18	Retainer	-0.66*(0.11)	-0.7*(.015)	Contact stress (localized)
19	Bearing	0.13	0.039	Max shear

NOTES

Failure criteria is Max shear ("Tresca") on main chamber components; combined tensile/shear on fasteners

* Margins of safety are due to localized phenomena based on conservative modeling techniques; "(xx)" indicates farfield stress.

** Does not reflect `33% increase in flange thickness.

*** Margins of safety do not reflect 5% reduction in load due to decrease of end-cap area.

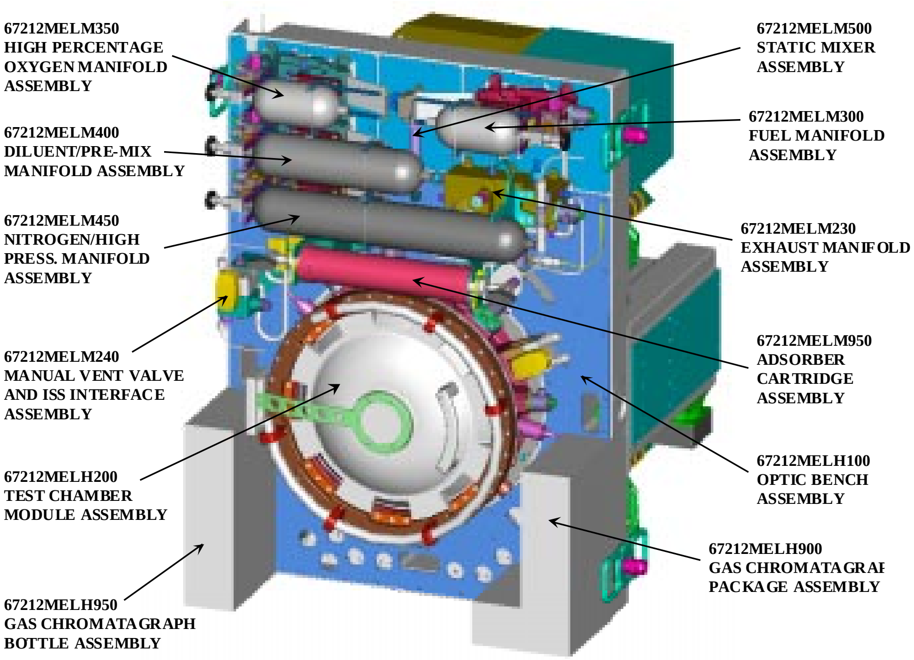
Fuel/Oxidizer Management Assembly (FOMA)

Requirements

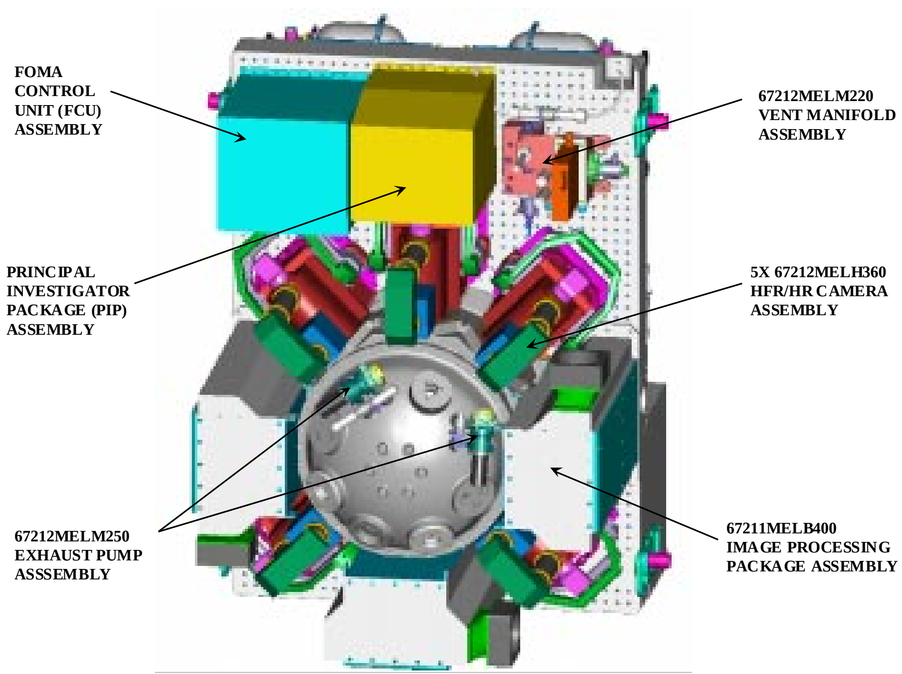
- Delivery/regulation of all gaseous fuels, diluents and oxidizers to the CIR Test Chamber
- Interface with ISS Nitrogen supply and Vacuum Exhaust System (VES)
- Performance requirements defined in FCF-DOC-002 SRED
- ISS VES requirements defined in SSP 57000 and SSP 30426 Contamination Control
- NSTS 1700.7B ISS Addendum

Description

- **Gas Supply and Distribution Package:**
  - On-orbit gas blending up to 3 gases
  - Flow-through with real time venting
  - Accommodate pre-mixed gases
- **Exhaust Vent Package (includes GC)**
  - Adsorber cartridge/re-circulation loop to clean post-combustion gases to ISS limits
  - Gas Chromatograph to sample Test Chamber environment



COMBUSTION OPTIC BENCH/FOMA ASSEMBLY (67212MELH100) FRONT VIEV



COMBUSTION OPTIC BENCH/FOMA ASSEMBLY (67212MELH100) REAR VIEW

Fuel/Oxidizer Management Assembly (FOMA)

Specifications/Features

- Gas supplied in 1.0, 2.25 and 3.8 liter stainless steel bottles (commercial)
- Bottles are keyed to assure proper installation
- Max. bottle pressure 14 MPa (2000 psi)
- Partial Pressure or Dynamic gas blending
- Gas blending weight savings: Factor of 4
- Pre-mixed gases
- Gas bottles and Adsorber Cartridge Crew replaceable
- Designed for maintainability to component level
- Manifolds direct gas flow, reduce tubing, minimize internal supply volume
- Normally closed valves
- Independent controls for over-pressurization
- Gas velocity in O2 lines < 100 ft/sec

Development Status/Test Results

- Successfully passes Phase 0/1 Payload Safety Review at JSC
- Interfaces evaluated at Crew Review, 11/98
- Gas Supply Manifold has been assembled and tested for leak and performance before and after vibration test
- Blending accuracy tests have been performed using both Partial Pressure and Dynamic methods
- Adsorber Cartridge sizing tests have been initiated to evaluate combustion by-products and liquid fuel adsorbtion
- Re-packaging of commercial Gas Chromatograph into smaller, maintainable volume has begun

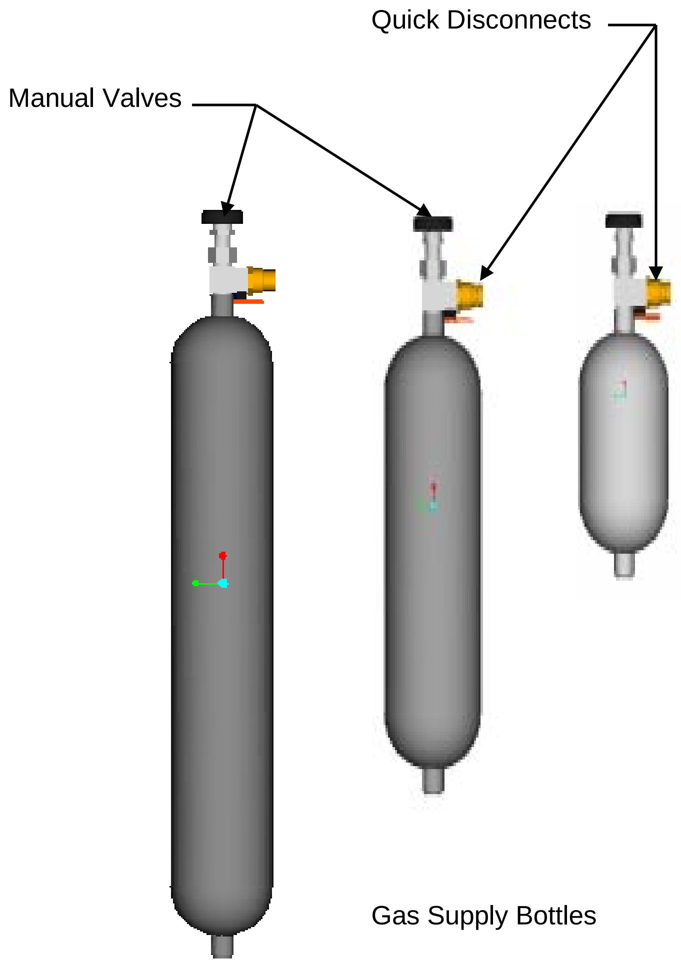
Fuel/Oxidizer Management Assembly (FOMA)

Gas Delivery Package

Gas Supply Bottles

- Bottle Sizes: 1.0, 2.25, 3.8 liter
- Bottle Weights:

  1.0L ~ 4 kg, 2.25L ~ 7.5 kg, 3.8L ~ 10.5 kg
- Oxidizers
  - 1.0 L up to 85% O2
  - 2.25 L up to 50% O2
  - 3.8 L up to 30% O2
- Fuels: 1.0 L and 2.25 L
- Diluents: 1.0L, 2.25L, 3.8 L
- Stainless steal, commercially available
- Quick disconnect attachment to manifold
- Pressure: ~14 MPa (~2000 psig)



Gas Supply Bottles

Fuel/Oxidizer Management Assembly (FOMA)

Gas Delivery Package (con't)

Oxidizer/Diluent Flow Rates

Max flow rate from each manifold:	30 SLM
Maximum flow rate, Total:	90 SLM

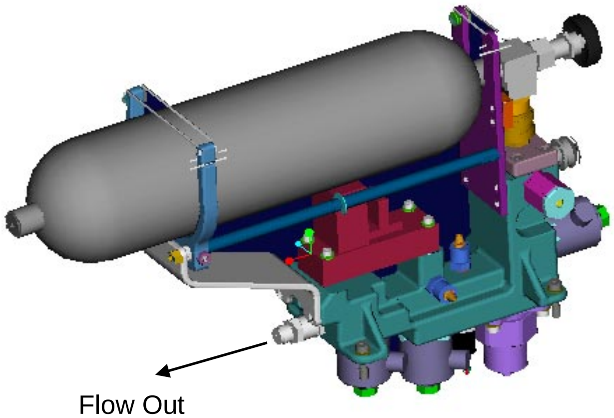
Fuel Flow Rate

Maximum flow rate (current):	2 SLM*

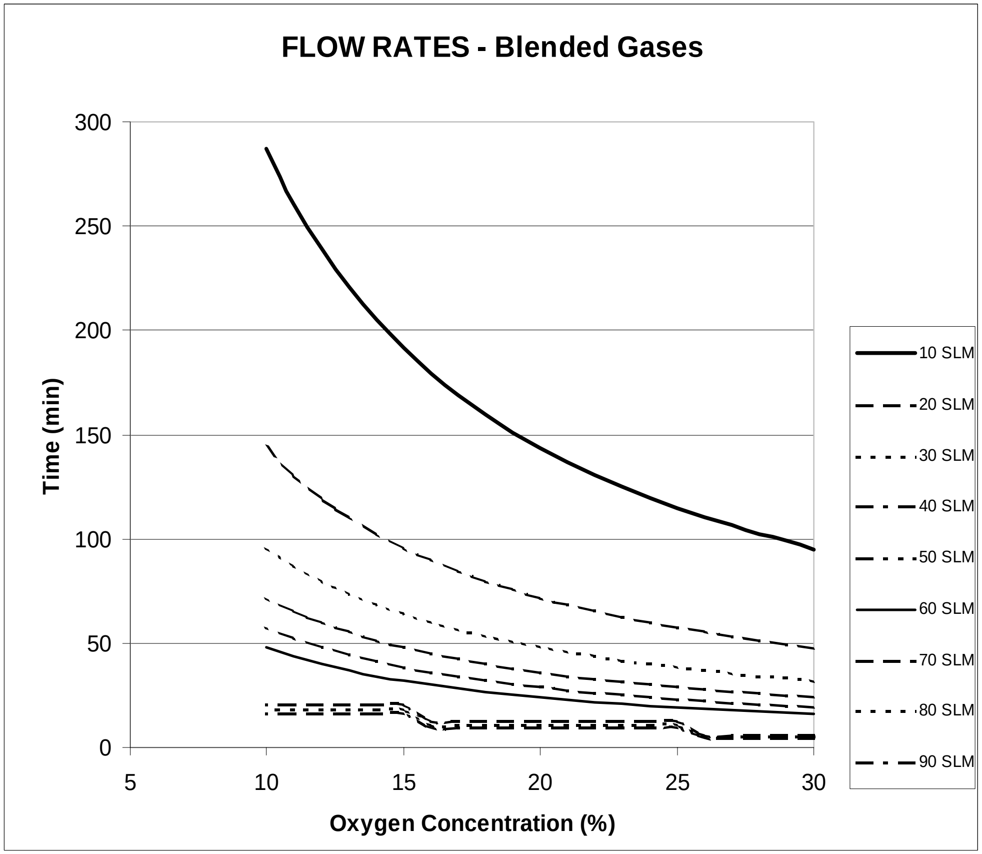
* Experiment replaceable for greater flow rates

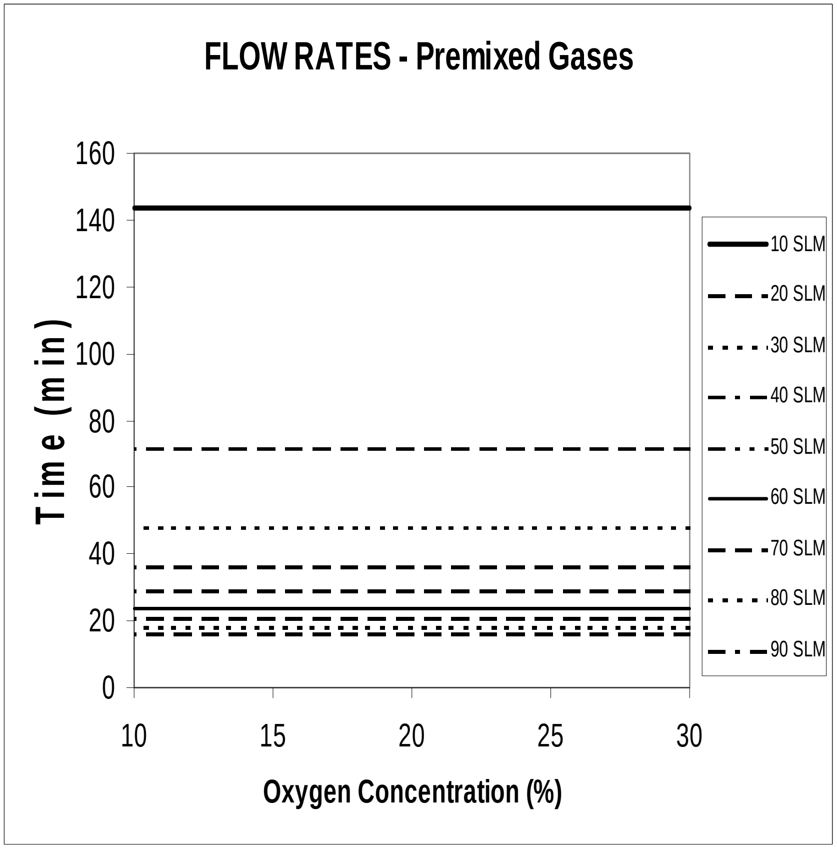
Development Status/Test Results

- Gas Blending Accuracy
  - Partial Pressure: < ± 0.2% absolute
  - Dynamic:
    - Oxygen blends <25%: ± 1.0% absolute
    - Oxygen blends >25%: ± 2.0% reading
- Flow Rate Accuracy: ± 1.0% of MFC full scale



Fuel/Oxidizer Management Assembly (FOMA)



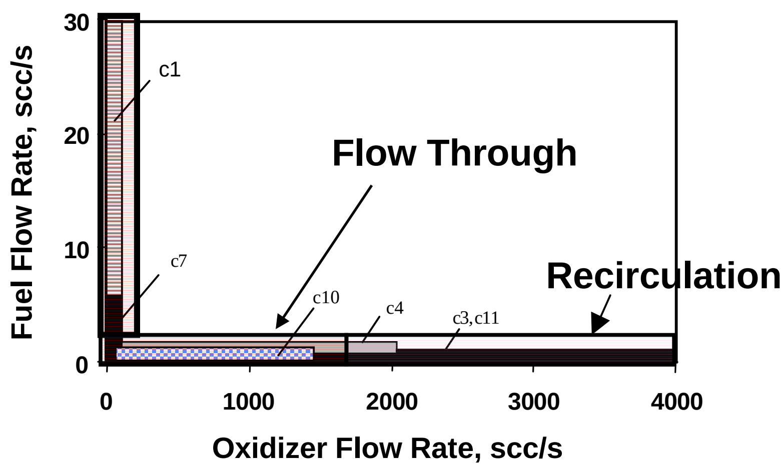


Fuel/Oxidizer Management Assembly (FOMA)

3.2.3 Initial Fluid Dynamic State *Req. C6 - Fluid Flow*

- FOMA Oxidizer Flow Through Mode Capability:
  1500 scc/s = 90 SLM
- SRED requirement: 4000 scc/s = 240 SLM

Fuel and Oxidizer Flow Rates



- Re-circulating flow can be used for flow rates >1500 scc/s using PI-hardware
- Requirement does not consider the effect of duration. For example:
  100 SLM x 30 min = 3,000 SL of gas
  (3.8L bottle has only 478 SL of gas)
- Packaging constraints within the CIR limit valve and tubing sizes
- Safety requires redundant controls, which increases number of components and adds pressure drops

Fuel/Oxidizer Management Assembly (FOMA)

- Design Issues to Implement Flow Through Capability at SRED specified flow rate of 4000 scc/s:

  - Gas Supply Package
    - High Percentage Oxygen MFC must stay at 30 SLM to keep oxidizer flow velocity under 100 ft/sec for mixtures having O2 > 30%
    - Remaining 2 MFC's would have to be 110 SLM Can not be down ported type - major impact to manifold packaging and Optic Bench placement
    - Current line sizes would not support high flow
    - Valves, tubing would need to increase
    - Bottle size/pressure would limit flow duration to 4 min at full flow

  - Exhaust Vent Package
    - MFC change from 100 SLM to 1000 SLM due to pressure drop
    - Exit Pressure Regulator resized for 3/4" line

- **Conclusion:**

  Requirement: "Flow-through capability must be maximized to the extent possible."

  Current FOMA design fulfills this intent within the packaging constraints of the CIR

Fuel/Oxidizer Management Assembly (FOMA)

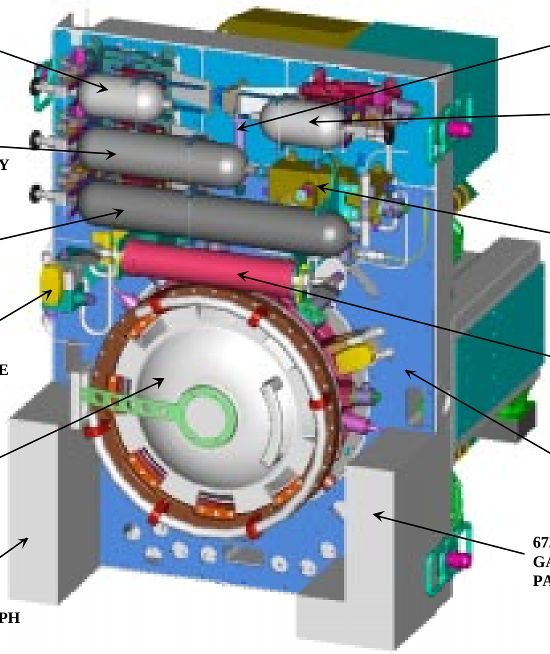
Exhaust Vent Package:

Requirements:

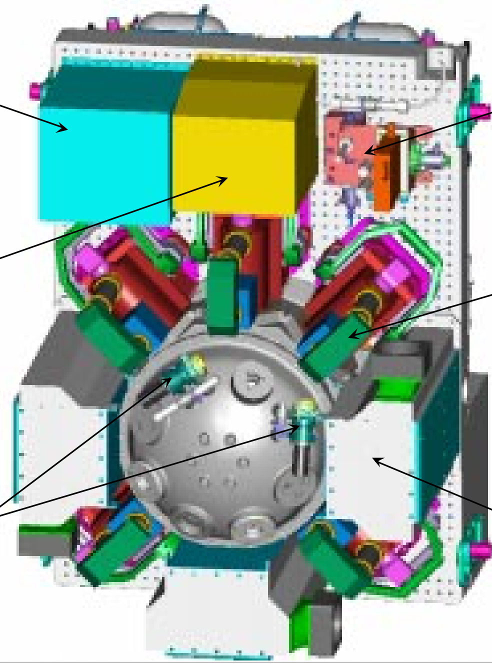
- ISS VES requirements specified in SSP 57000
  - Dew point of 16° C or less
  - Pressure of 276 kPa (40 psia) or less
  - Max. particulate size 100 microns
  - Acceptable vent gases: Cabin Air, ISS pressurized gases; N2, CO2, Ar, He
  - All other gas mixtures require reaction and adhesion verification analysis as specified in ISS PIRN 57000-NA-132 (currently being reviewed)

Description:

- Connects the CIR Test Chamber with the ISS VES
- Located on both the front and back of the Optics Bench
- Approximate Package weight: 24 kg
- Sub-Systems:
  - Re-Circulation Loop
  - Gas Chromatograph (GC)



COMBUSTION OPTIC BENCH/FOMA ASSEMBLY (67212MELH100) FRONT VIEW



COMBUSTION OPTIC BENCH/FOMA ASSEMBLY (67212MELH100) REAR VIEW

Fuel/Oxidizer Management Assembly (FOMA)

Exhaust Vent Package - Re-Circulation Loop

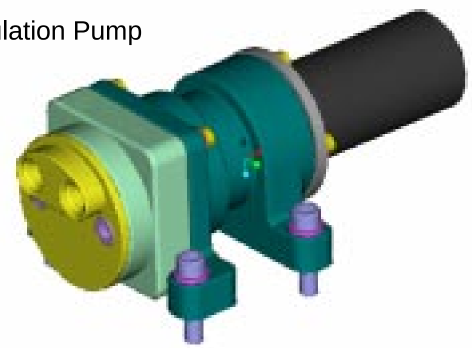
Description

- Major Components:
  - Adsorber cartridge
  - Re-Circulation Pumps

Specifications/Features

- Magnetically coupled Re-Circulation Pumps (2)
- Max re-circulation flow rate: 20 SLM
- 3 sizes of Adsorber Cartridges
  - 76.2 mm ID x 355 mm long
  - 50.8 mm ID x 279 mm long
  - 25.4 mm ID x 203 mm long
- Adsorber Cartridges have QD connections for Crew replacement
- Adsorber Cartridge contents:
  - Silica gel: removes water, alcohols, aromatics, olefins
  - Molecular sieve: removes water
  - Activated carbon: removes hydrocarbons
  - Lithium hydroxide: removes CO_2 and acid gases

Re-Circulation Pump



Adsorber Cartridges

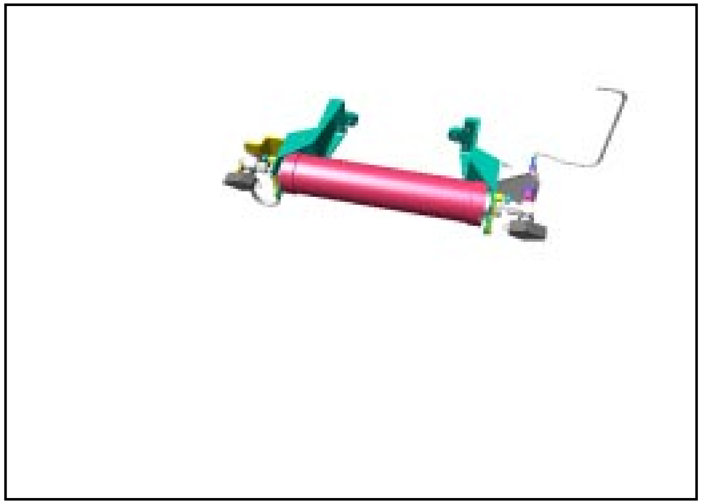
Fuel/Oxidizer Management Assembly (FOMA)

Development Status/Test Results

- Extensive testing using FOMA Breadboard
  - Dew Point Tests (silica gel vs. molecular sieve
  - Lithium Hydroxide Efficiency Tests
  - Liquid Fuel Adsorption Tests
  - By-Products of Combustion Tests

- Experiment Specific Adsorber Characterization Tests
  - Combustion By-Products from:
    SIBAL
    DCE
    BCDCE
  - All 3 experiments require only one 50.8 mm ID Adsorber Cartridge (each with different media)

- Adsorber Cartridge removal/installation was evaluated at a Crew Review in November 1998



Fuel/Oxidizer Management Assembly (FOMA)

Exhaust Vent Package - Gas Chromatograph

Requirements

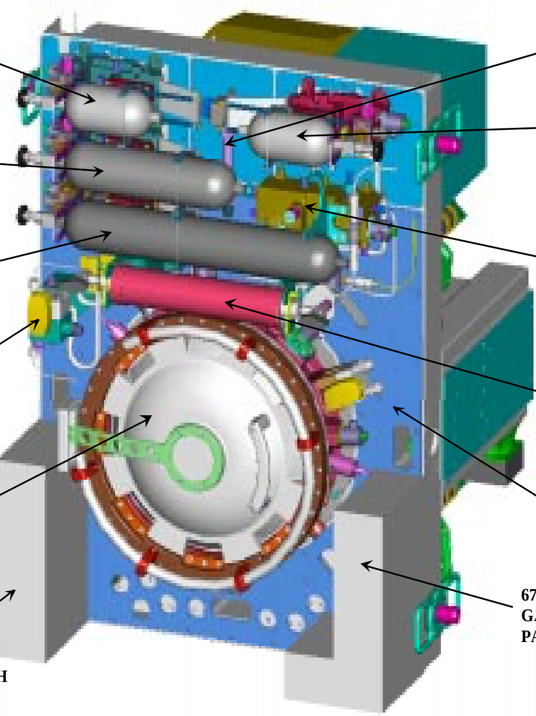
- Analyze CIR Test Chamber environment, both pre- and post combustion
- Sampling required prior to venting to ISS VES to assure ISS limits are not exceeded

Description

Repackaged commercial micro-GC unit

- launched in stowage
- one electrical connection
- five fluid line connections (QD's)
- retractable/removal handle
- bottom right of Optic Bench

Carrier gas and calibration bottles located in the bottom left corner on the front of the optics plate.

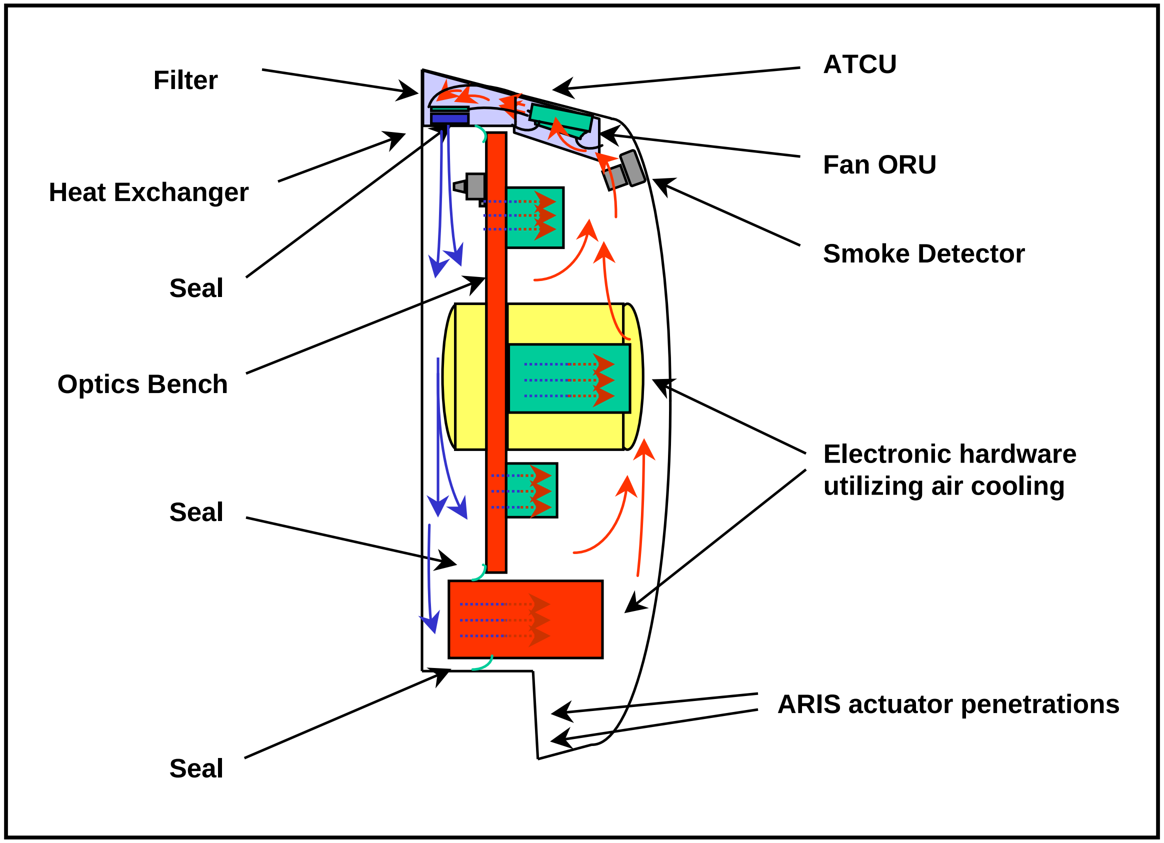


COMBUSTION OPTIC BENCH/FOMA ASSEMBLY (67212MELH100) FRONT VIEW

ECS Overview - Air Thermal Control Subsystem (ATCS)

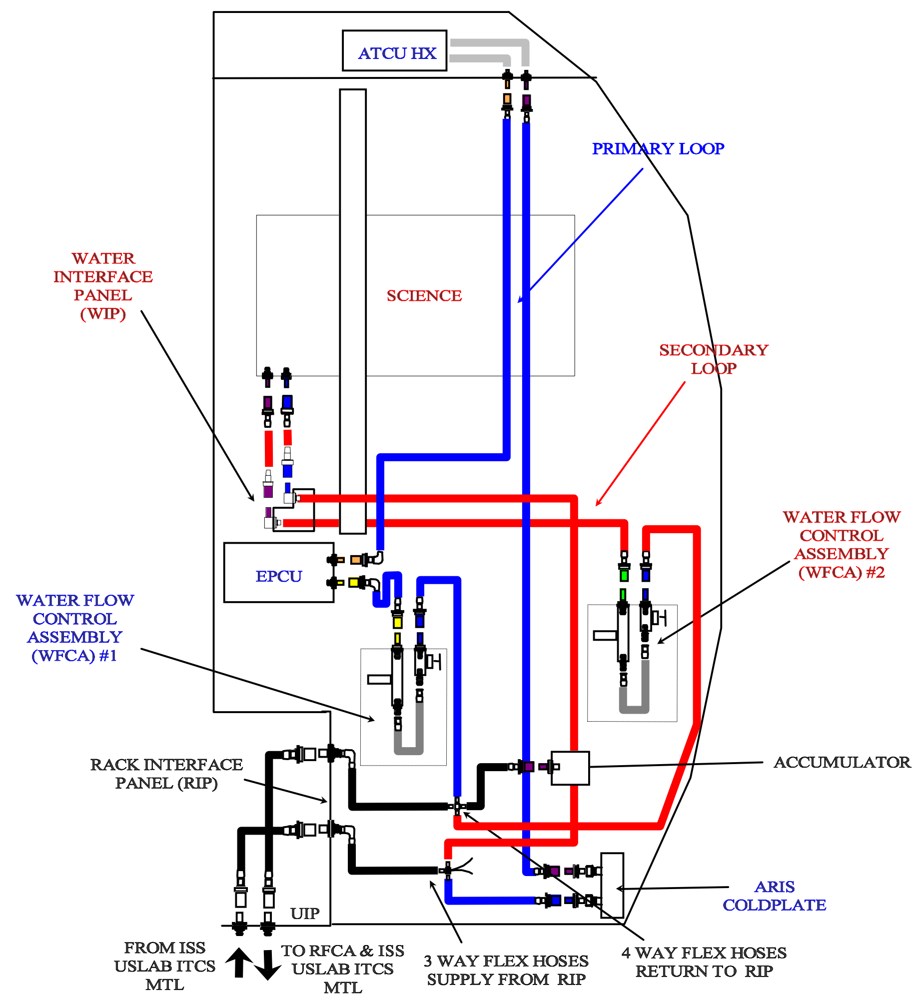
- The Air Thermal Control Subsystem (ATCS) removes waste thermal energy from the CIR internal atmosphere.
- ATCS hardware is located in the Air Thermal Control Unit (ATCU). The ATCU structure is located at the top of each Facility rack.
- ATCU fans draw warm air from the rear of the rack and force the air through an air filter and heat exchanger. The cool air flows out of the ATCU into the front of the rack.
- The front and rear of the rack the rack are separated by the Optics Bench. The Optics Bench has a low-pressure seal separating the front of the rack from the rear. Heat generating, electronic equipment is mounted to the optics bench at the Universal Mounting Locations (UMLs). Ports in the UMLs permit airflow to pass through the air cooled hardware attached to the Optics Bench at the UMLs.
- External ducting and baffling and the associated mass and volume are minimized by the ATCS design.

- This novel rack air cooling design eliminates last minute system flow balancing, permits easy on-orbit reconfiguration and eliminates extensive system level ground based testing.

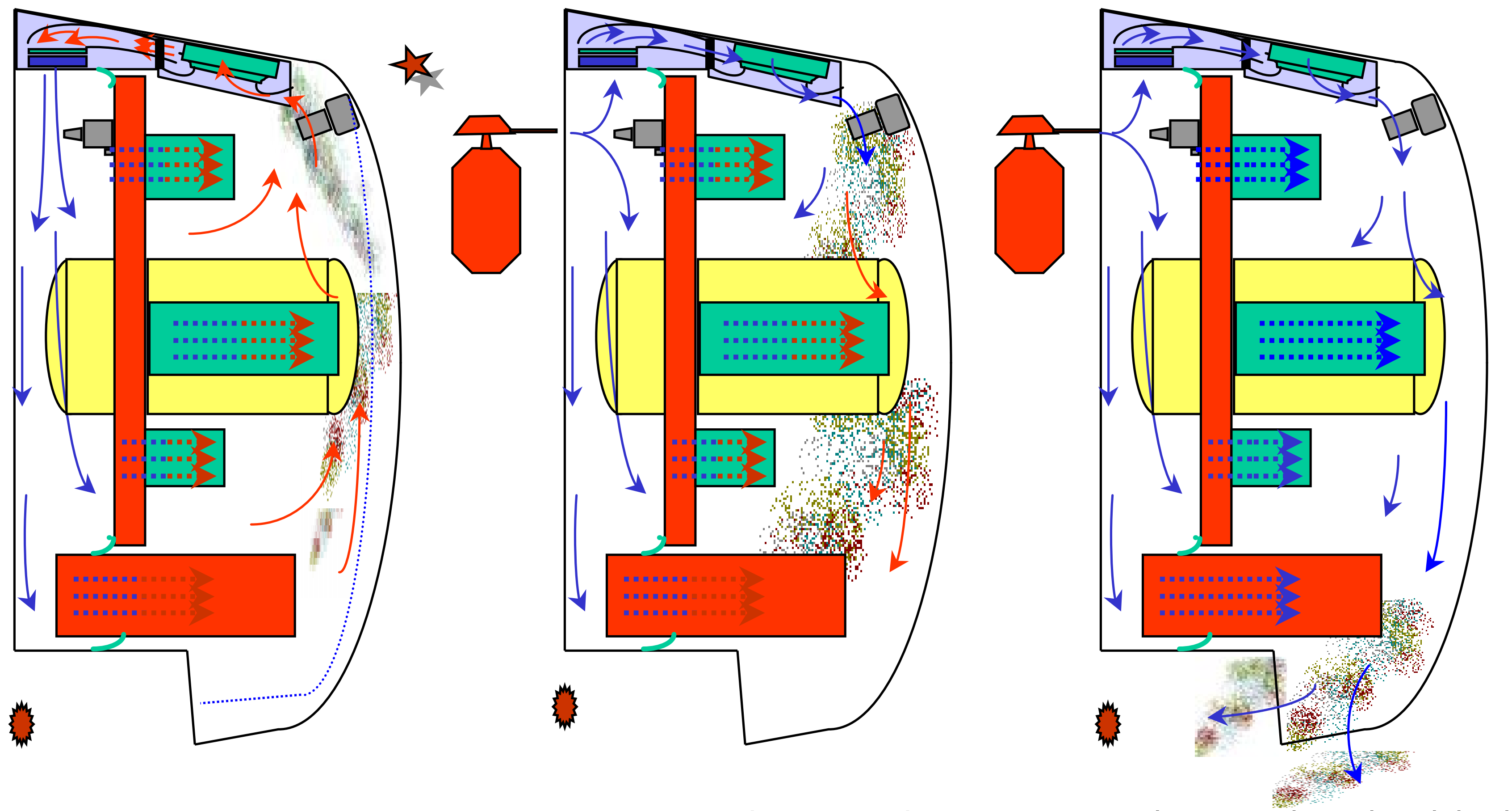


ECS Overview - Water Thermal Control Subsystem (WTCS)

- The WTCS provides cooling of all facility equipment in all three racks by removing all the waste thermal energy generated by Facility systems and transferring it to the International Space Station (ISS) Internal Thermal Control System (ITCS) Moderate Temperature Loop (MTL). The Primary Loop includes all non-science hardware. The Secondary Loop includes all science hardware.
- Thermal energy is removed either directly from the coldplates or indirectly from the Air Thermal Control Unit (ATCU) air to water heat exchanger. Each of the three Facility racks contains an identical and independent WTCS. The WTCS consists of two loops. Each loop is capable of delivering up to 300 lbm/hr of water for a combined maximum of 600 lbm/hr. With a combined maximum of 600 lbm/hr the maximum cooling capability for each rack is just over 6kW with inlet and outlet temperatures of 65°F (18.3°C) to 100°F (37.8°C), respectively.
- We are using a common procurement with the Material Science Research Rack (MSRR-1) for purchase of the Water Flow Control Assemblies (WFCAs.)
- The water flow rate is a function of the total power being dissipated by each rack. ISS ITCS MTL requirements dictate the amount of water available. The inlet water temperature to the racks is 65°F (18.3°C). The water flow rate will be such that the minimum water exit temperature is 100°F (37.8°C). This water flow rate corresponds to about 97.5 lbm/hr per 1 kW of power.



ECS Overview - Fire Detection and Suppression Subsystem (FDSS)

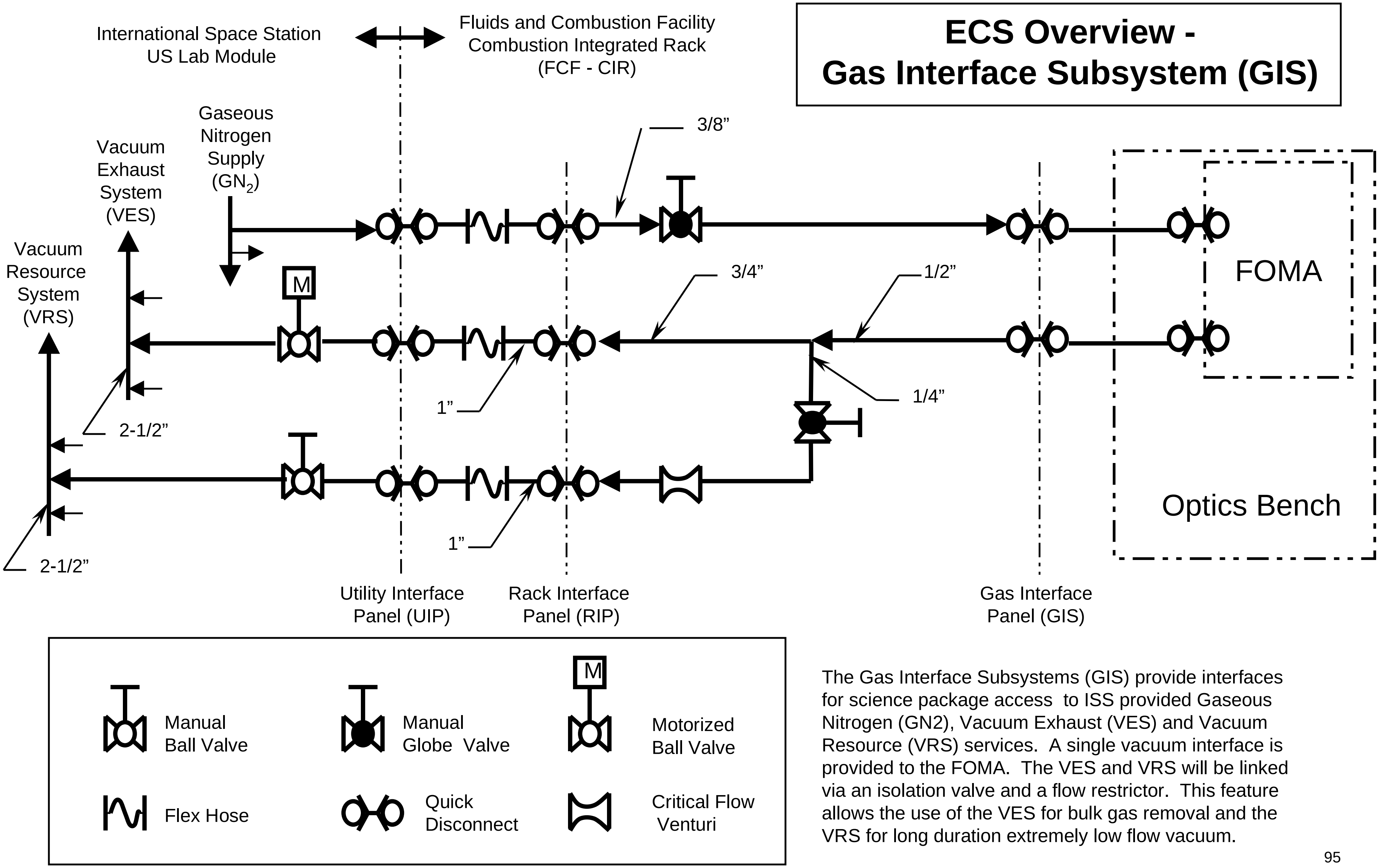


Step 1. Smoke Detector indicates a fire event signals ISS systems which shut off power and alerts the crew.

Step 2. Crew inserts and dispenses portable fire extinguisher (PFE) into access port in rack door.

Step 3. Fire event is extinguished.

ECS Overview - Gas Interface Subsystem (GIS)



The Gas Interface Subsystems (GIS) provide interfaces for science package access to ISS provided Gaseous Nitrogen (GN2), Vacuum Exhaust (VES) and Vacuum Resource (VRS) services. A single vacuum interface is provided to the FOMA. The VES and VRS will be linked via an isolation valve and a flow restrictor. This feature allows the use of the VES for bulk gas removal and the VRS for long duration extremely low flow vacuum.

Air Thermal Control Subsystem - Air Thermal Control Unit (ATCU)

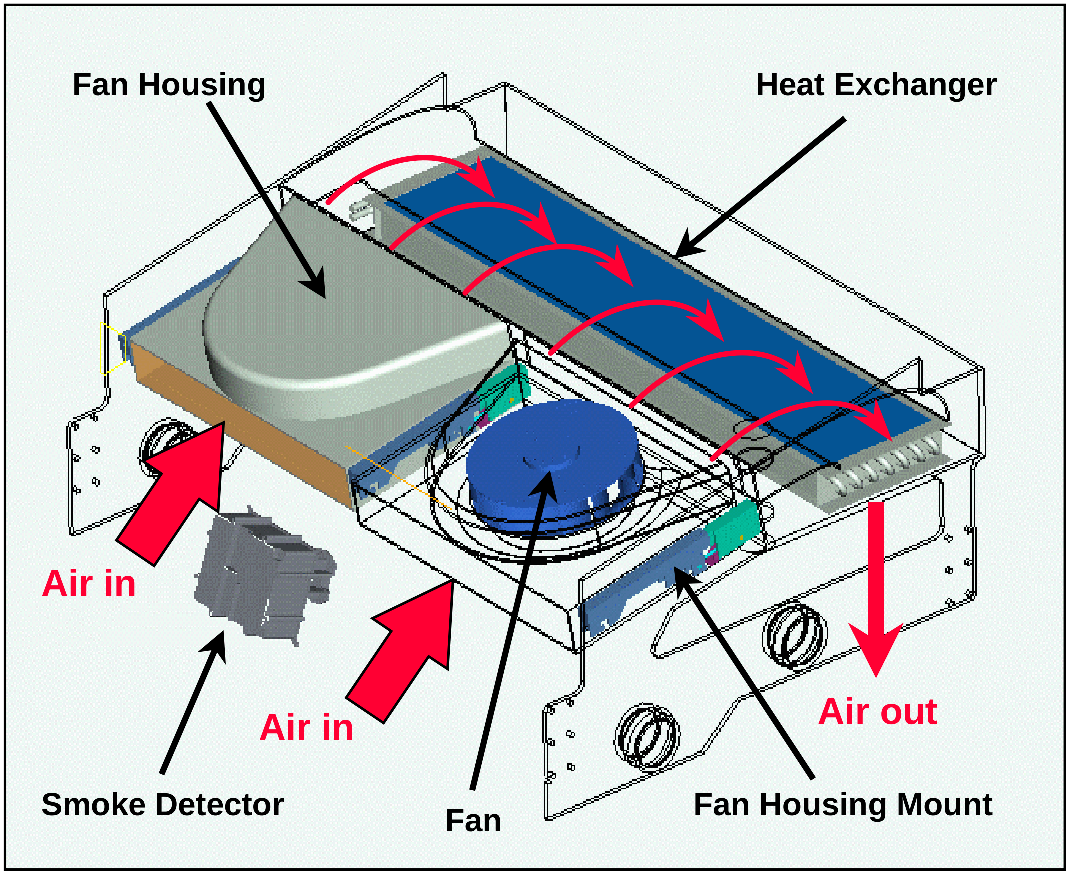
Air Thermal Control Unit Features:

- Two backward curved impellers drive the airflow.
- One air to water heat exchanger rejects waste heat to the Moderate Temperature Loop.
- Heat exchanger volume:
- 32.0 in x 6.2 in x 1.3 in
- The Air Thermal Control Unit transfers launch loads from the Optics Bench to the rack structure.
- Fan and Fan Housing are Orbital Replacement Units. Fan Housing design provides passive Microgravity disturbance isolation.
- The ATCU provides air cooling, rack stiffening, structural support, and airflow for fire detection.
- Air Volumetric Flow Rate: 165 CFM.
- Pressure Difference Provided: 0.4 in. H_2O

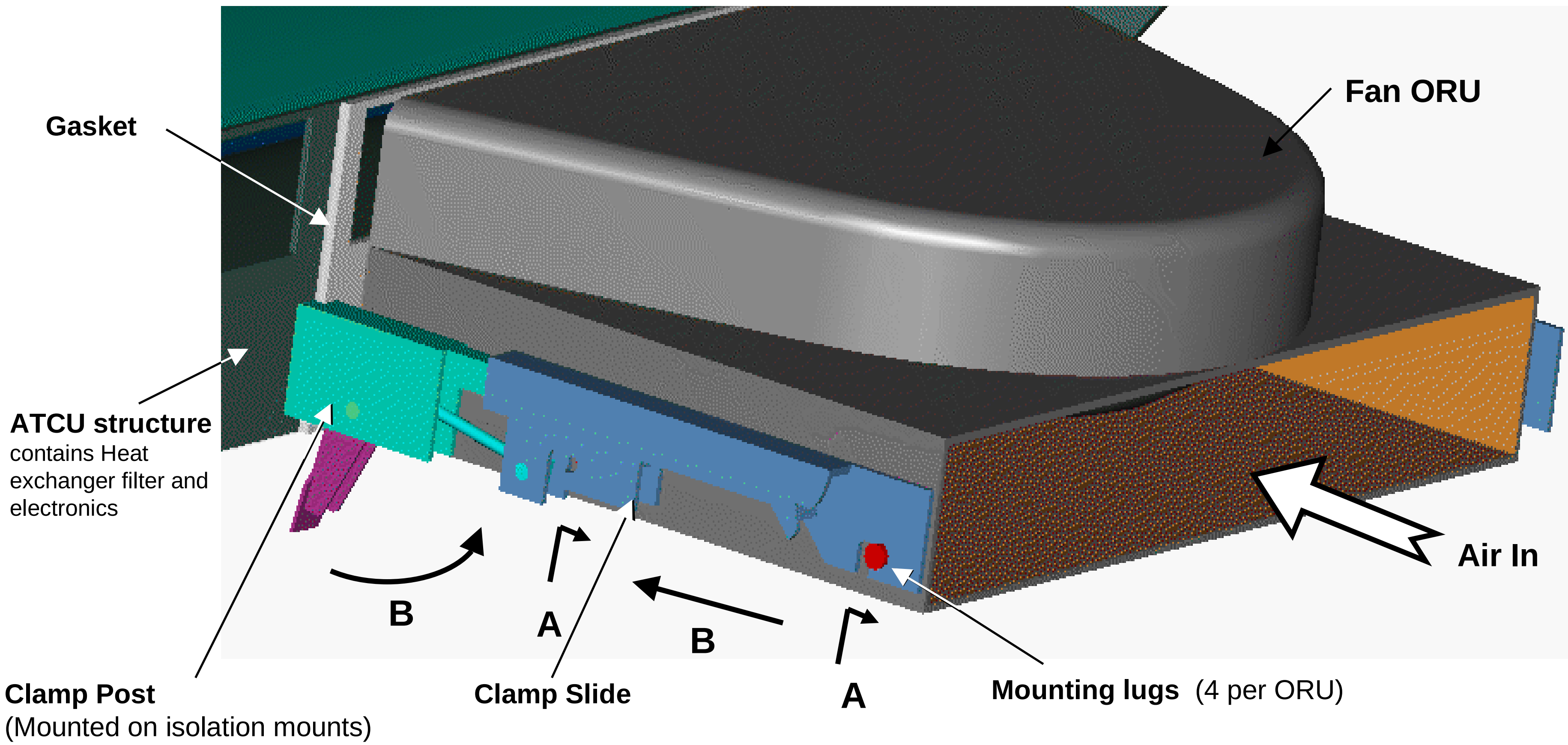
Air Cooling Capacities:

	Watts	Air Supply	Air Return
Design	1500 W	78^oF	109^oF
Off Design 1	2000 W	81^oF	112^oF
Off Design 2	2500 W	81^oF	121^oF

- The Air Thermal Control Unit (ATCU) is specifically designed to occupy the top of the Combustion Integrated Rack. The shape and location of the ATCU maximizes the volume available for combustion science hardware.



ATCU Fan Orbital Replacement Unit (ORU) Installation



A. Insert Fan ORU into the slots in the clamp slide mechanism
B. Engaging the over the center clamp slides the fan ORU forward into the ATCU structure against the gasket that provides both a seal and vibration and acoustic damping

Air Thermal Control Subsystem Testing

Individual Fan Testing

Commercial-off-the-shelf (COTS) fans were evaluated for use in the Air Thermal Control System. Fans with different pressure drop/flow rate characteristics were evaluated in terms of volume/geometry, acoustic noise generation and power requirements/efficiency.

Heat Exchanger Testing

Potential flight heat exchangers were selected based on results of heat exchanger testing. An efficient air to water heat exchanger will enable conservation of cooling water and will minimize heat exchanger volume while meeting component temperature requirements. Selected heat exchangers meet pressure drop and leakage requirements.

Future Airflow Testing Plans

- Performing Fluid Integrated Rack(FIR) testing to evaluate commonality of the Air Thermal Control System.
- Performing an Engineering Model precursor test of the ATCU fan housing.
- ATCU Engineering Model testing is scheduled for early in Fiscal Year 2000.

Rack Airflow Testing

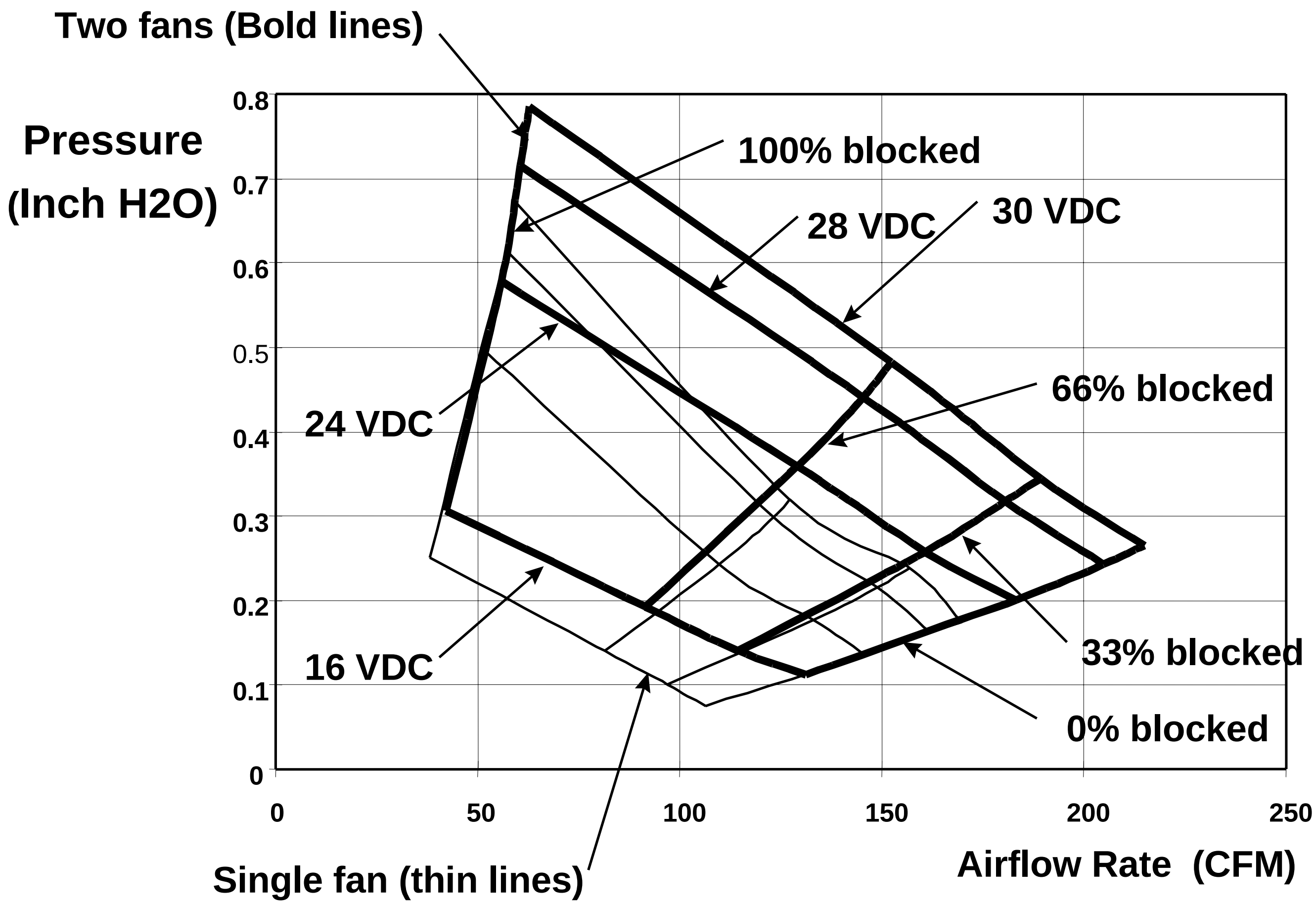
Rack Airflow Tests have been conducted to evaluate system level performance using fans that performed well during individual fan tests.

The following concerns were addressed:

- Validated the rack pressure drop analysis and the fan sizing analyses
- Determined the impact of leakage around the Optics Bench
- Determined the impact of air exchange between the rack and the outside environment.
- Tested airflow system capability in both one fan and two fan operating modes.
- Tested door sealing concepts.
- Performed flow visualization tests to demonstrate that there are no air flow dead zones.
- High fidelity mockup rack airflow testing of door seals.

Results from Rack Airflow Testing

Validation of ATCU Fan Size



This family of curves shows measured performance of the ATCU in the CIR mock-up rack. The bold lines indicate performance with two fans operating at the same voltage. The thin line indicates performance with only one fan operating. In both cases the fans were run at 16, 24, 28 and 30 VDC. To generate the performance curves, rack airflow resistance was increased by blocking air passages by 100%,66%, 33% and 0%.

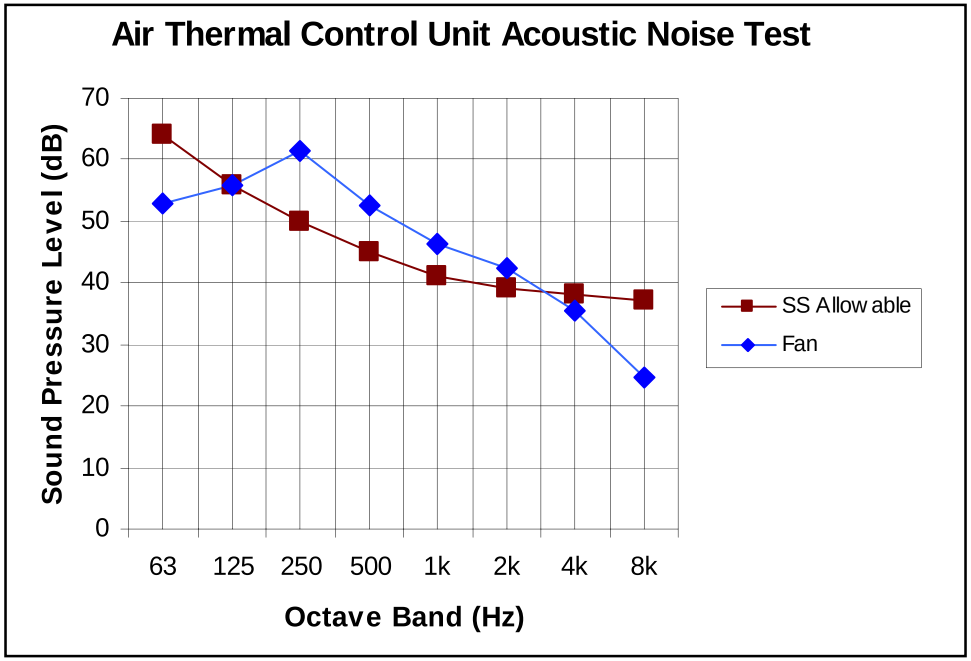
ATCS Acoustic, Microgravity and Stress Analysis Status

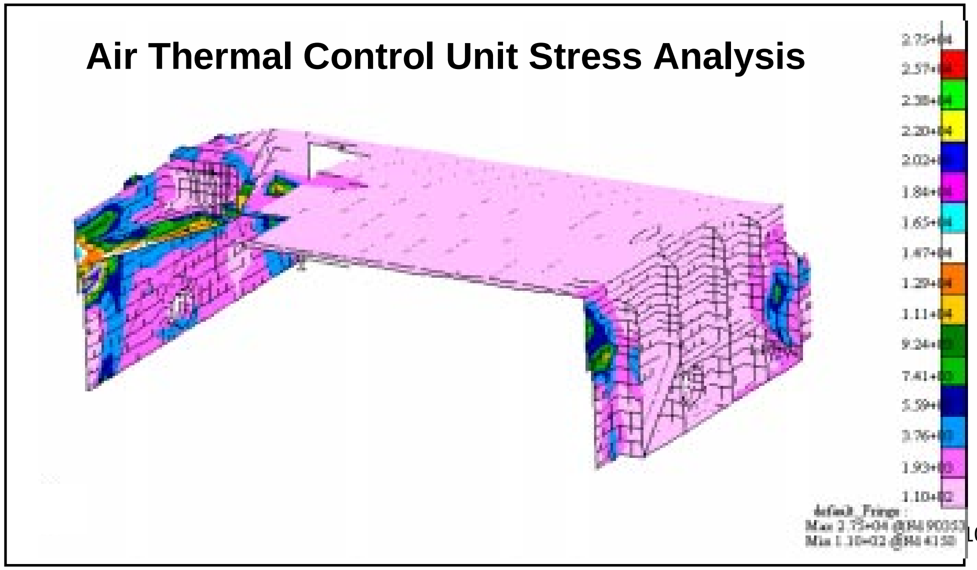
Air Thermal Control Unit Mockup Model Acoustic Noise Test

A quick acoustic noise test was performed on the Air Thermal Control Unit ATCU mockup Model. Space Station allowable sound pressure levels were exceeded at octave band frequencies (250 Hz, 500 Hz, 1000 Hz and 2000 Hz. These are worst case results. The acoustic test was conducted in a reverberant chamber (reflected sound was not attenuated) and the ATCU mockup was outside of the rack (no acoustic shielding from the rack structure). Due to stringent Space Station acoustic noise requirements, this issue is being closely monitored and acoustic noise minimization is a design requirement.

Air Thermal Control Unit Engineering Model Stress Analysis

The ATCU Engineering Model design is sufficient to handle and distribute anticipated launch loads. However, the fasteners attaching the ATCU to the ISPR posts have negative structural margin. Re-analysis and/or re-design of the ATCU attachment is required.





MAJOR WTCS HARDWARE DESCRIPTION

Water Flow Control Assembly (WFCA)

The WFCA consists of:

- ***Remote Flow Control Valve*:** It is an electronic valve that provides a fixed resistance to control flow to components requiring coolant, and isolates different areas of the system for protection, and coolant conservation. The flow range of the valve is 25 - 300 lbm/hr.
- ***Flow Meter***: It measures the coolant flow rate. It has a measured range of 25 to 300 lbm/hr.
- ***Temperature Sensor*:** It measures the coolant temperature. It has an operating range of -55^{o}C to +70^{o}C.

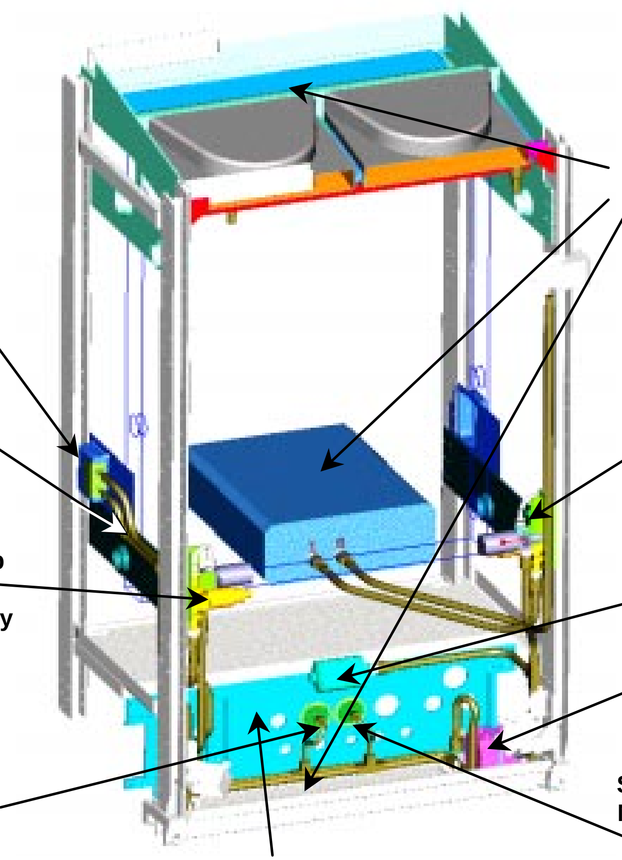
Self-Sealing Fluid Quick Disconnects

QDs are used to provide component connection and isolation for component maintenance, replacement and rack reconfiguration. Fluid disconnect halves are self-sealing with virtually no leakage or air inclusion during mate/demate operation.

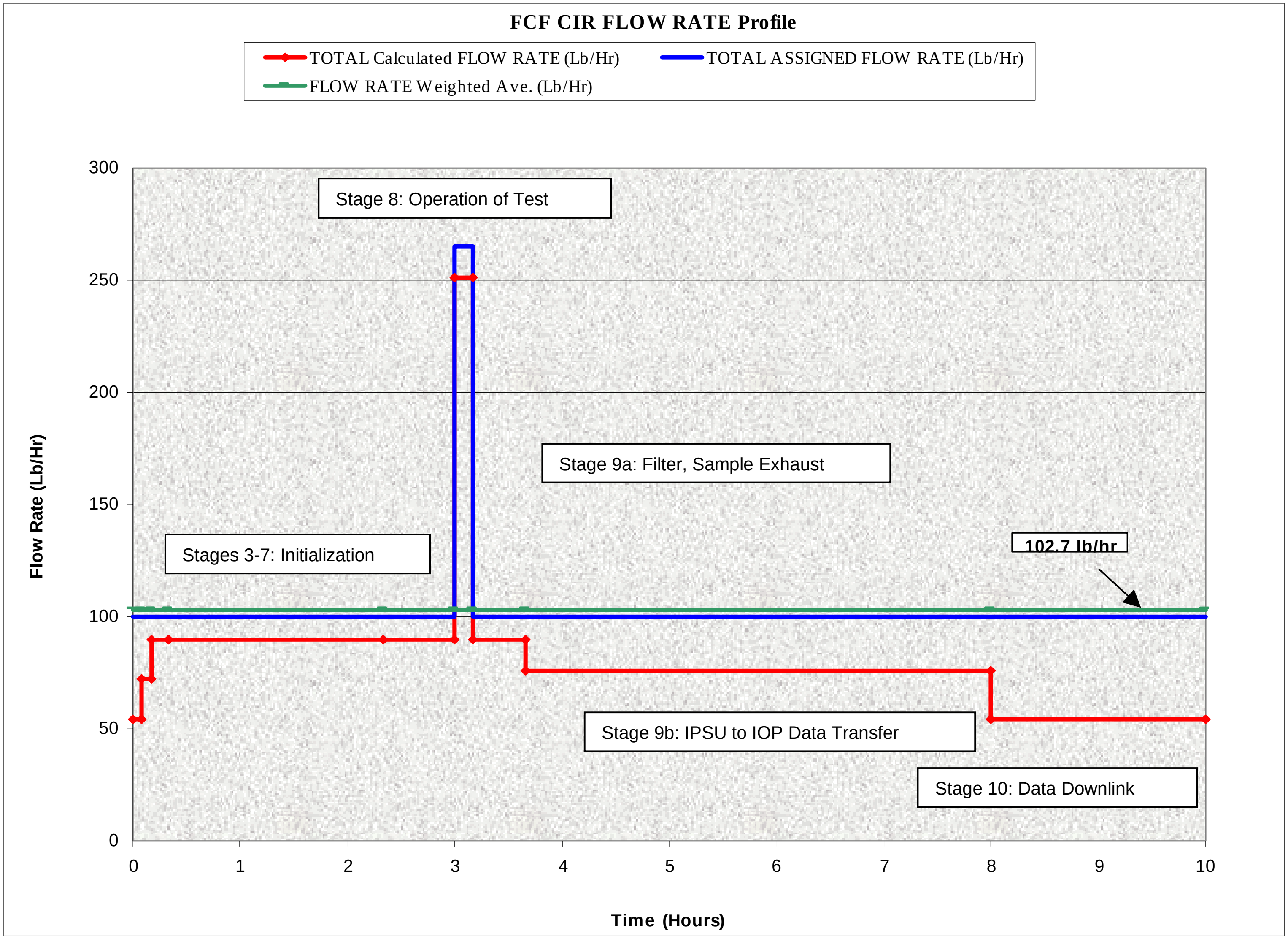
Accumulator

Absorbs differential thermal expansion due to temperature fluctuations.

WATER THERMAL CONTROL DESIGN

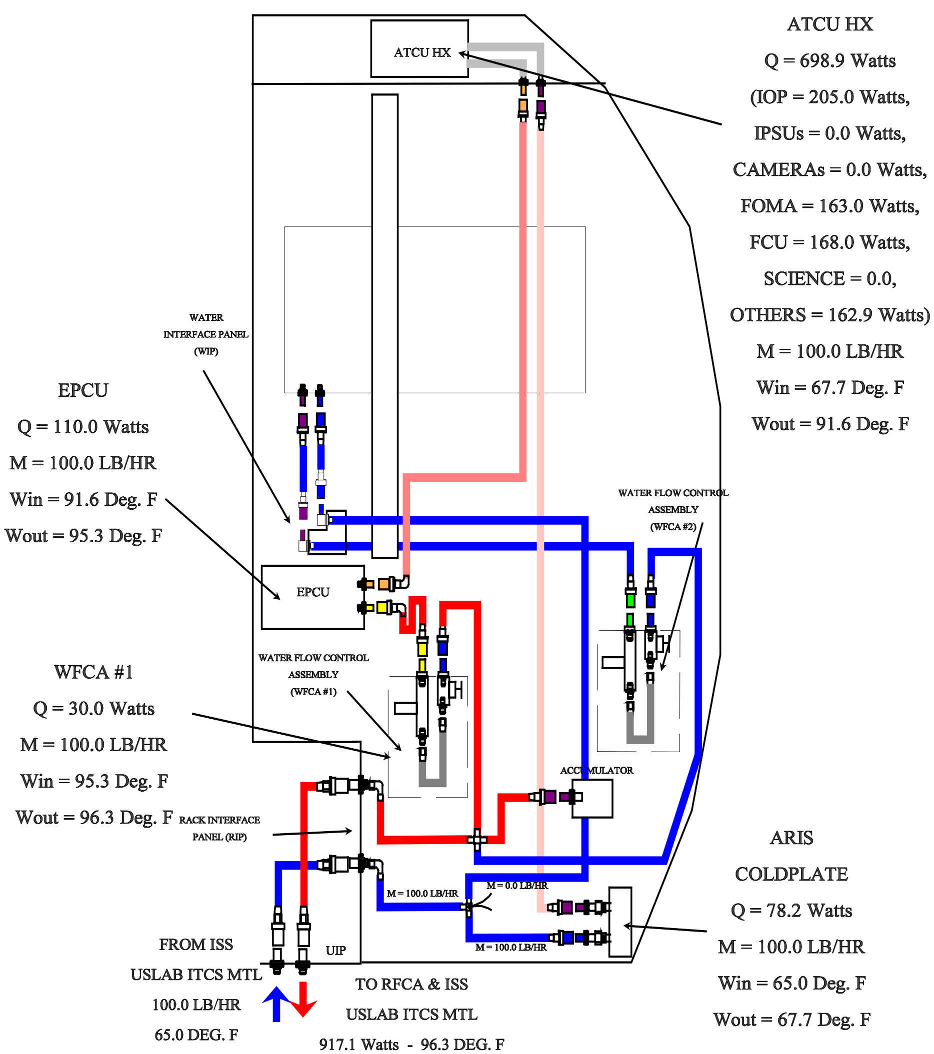


Typical Water CIR Flow Rate Profile

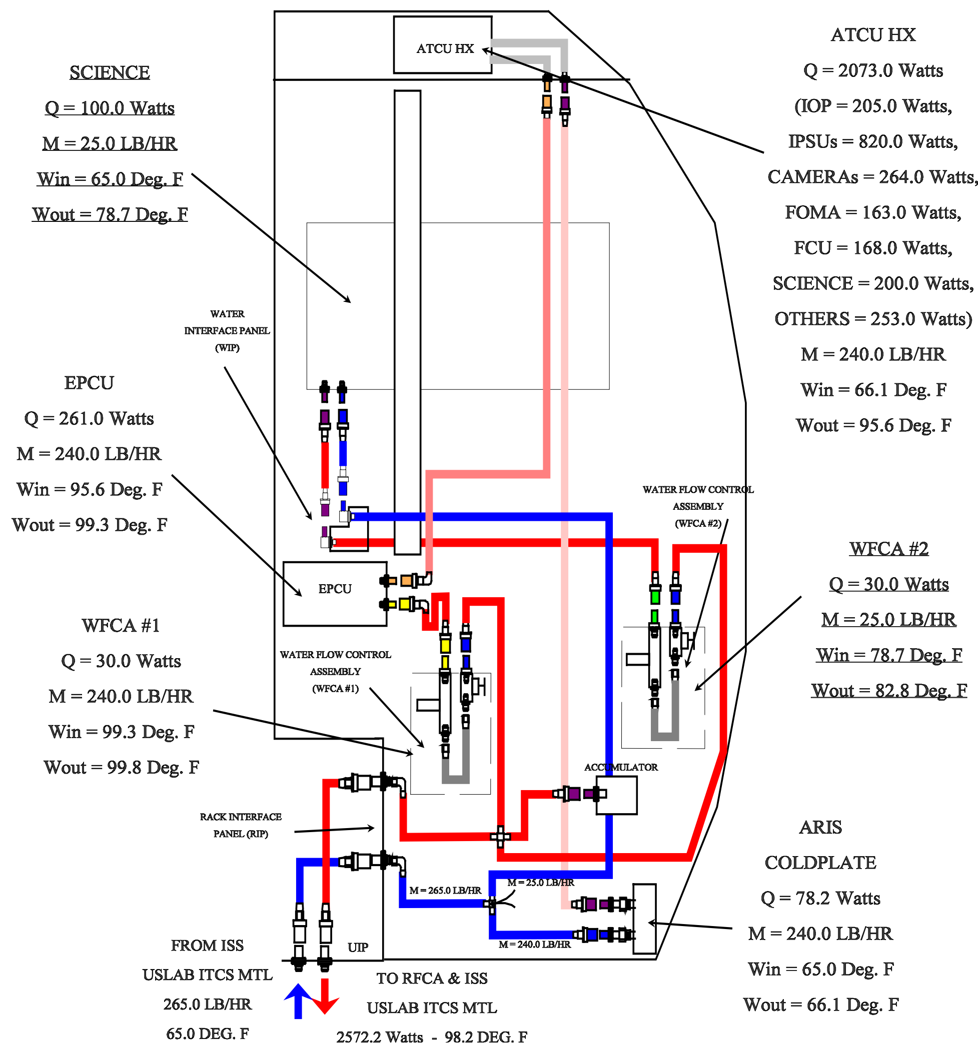


Space Station Fluids and Combustion Facility

CIR Nominal Power Profile



CIR Peak Power Profile

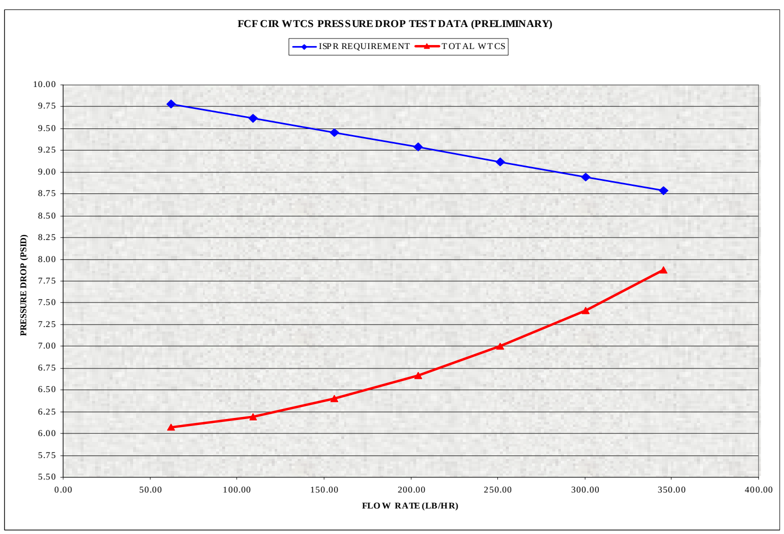


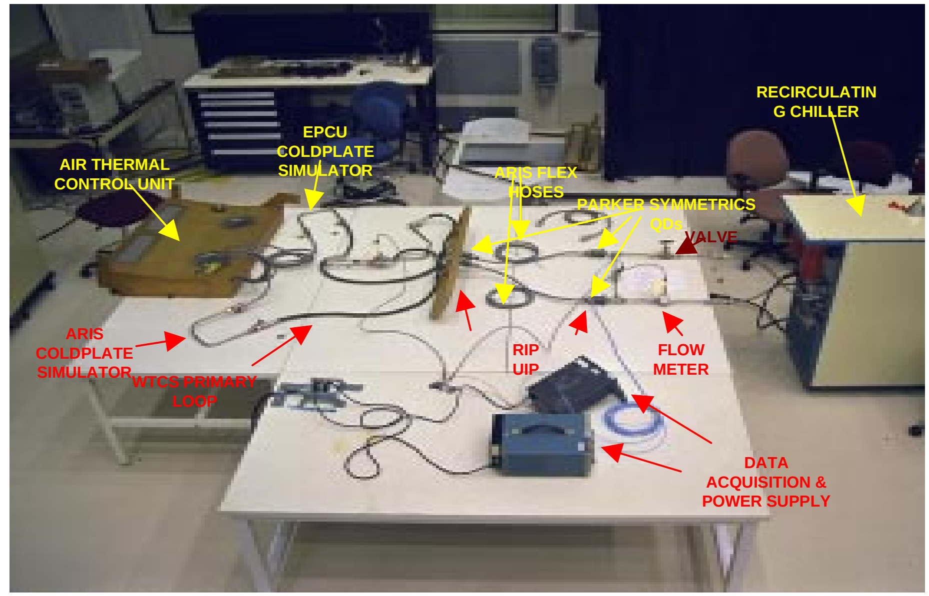
Engineering Model Component Tests

The purpose of the Engineering Model/Development tests is to investigate and resolve technical issues in support of the WTCS design. Part I investigated the WTCS primary and secondary loop pressure drop over the range of operating flow rates.

Primary loop pressure DROP:

- The total subsystem primary loop (w/o the WFCA) pressure drop at the expected maximum flow rate of 300 lb/hr is 5.9 psid.
- The WFCA maximum pressure drop requirement @ 300 lb/hr is 1.5 psid.
- Therefore, the total subsystem primary loop with the WFCA pressure drop at the expected maximum flow rate of 300 lb/hr is 5.9+1.5 = 7.4 psid, well within the maximum pressure drop requirement of 8.95 psid.





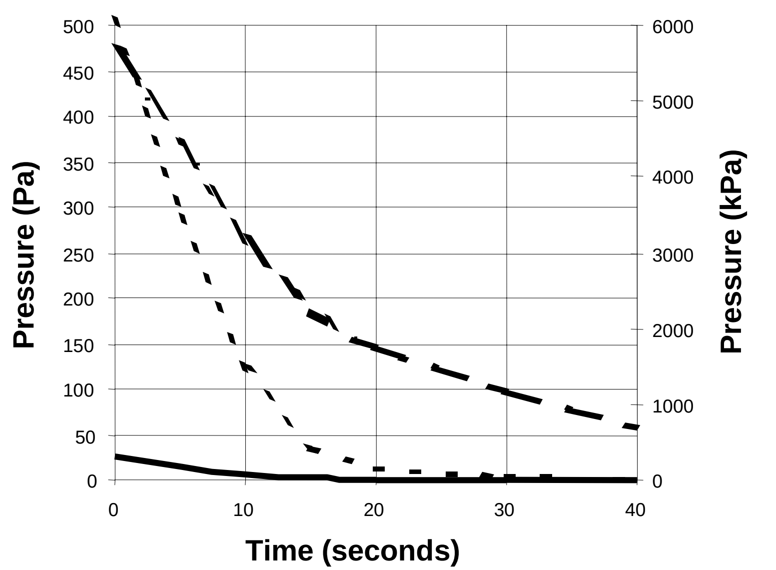
Secondary loop pressure DROP:

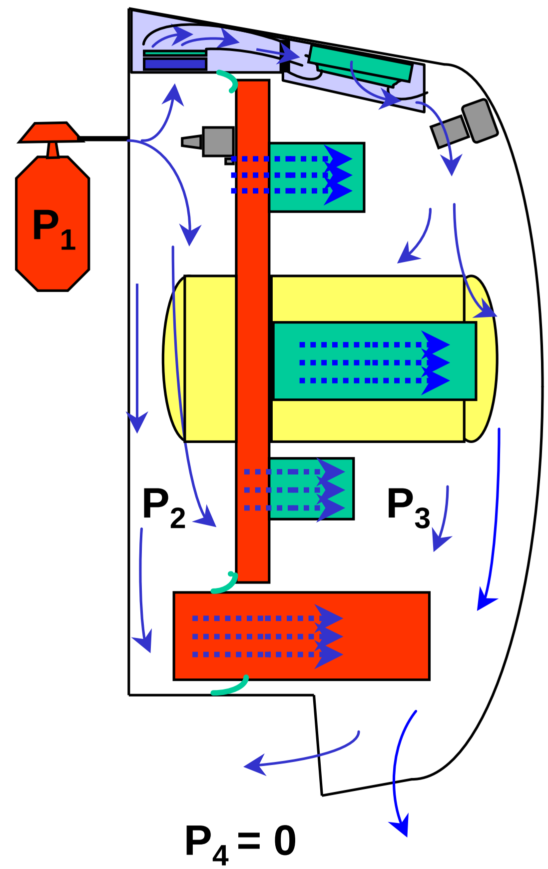
- The total subsystem secondary loop (w/o the WFCA) pressure drop at the expected maximum flow rate of 300 lb/Hr is 1.1 psid.
- If the “required” WFCA pressure drop is added to this, then the total subsystem secondary loop with the WFCA pressure drop (*1) at the expected maximum flow rate of 300 lb/hr is 2.6 psid.
- (*1): This total does not include the pressure drop due to Science Packages, which could be, at 300 lb/hr, as much as 8.95–2.6 = 6.35 psid.

Portable Fire Extinguisher (PFE) Discharge Characteristics

• Free volume of Rack	1000 liter
• Total volume discharged	1365 liter
• Worst case oxygen concentration (perfect mixing - required to be less than 10.5%)	8.9%
• Total mass discharged in 45 seconds	2.57 kg
• Max. discharge rate of PFE	6370 lpm
• Max. force acting on the doors	765 N
• Max. force acting on the optics bench	560 N

Worst Case Rack Pressure During PFE discharge *





P_1 Max = 5650 kPa Absolute
P_2 Max = 500 Pa Gage
P_3 Max = 25 Pa Gage

* Assumes rack configured for 283 lpm @ 100 Pa

Gas Interface System Interconnection to FOMA

Gaseous Nitrogen Subsystem

Provides interface between ISS provided nitrogen supply and FOMA.

Capabilities: (ISS provided)

- Maximum flow 4.4 kg/s
- Supply pressure 517 to 827 kPa

Features:

- CIR provided hand valve for positive shut-off
- Connection to FOMA via hose equipped with QD's

(Must be removed prior to translation of Optics Bench)

Vacuum Subsystem

Provides interface between ISS provided VES and VRS and the FOMA

Capabilities: (ISS Provided)

VES - Throughput of 0.13Pa*liter*s @ pressure of 0.1 Pa

VRS - maintains pressure of .1 torr or less

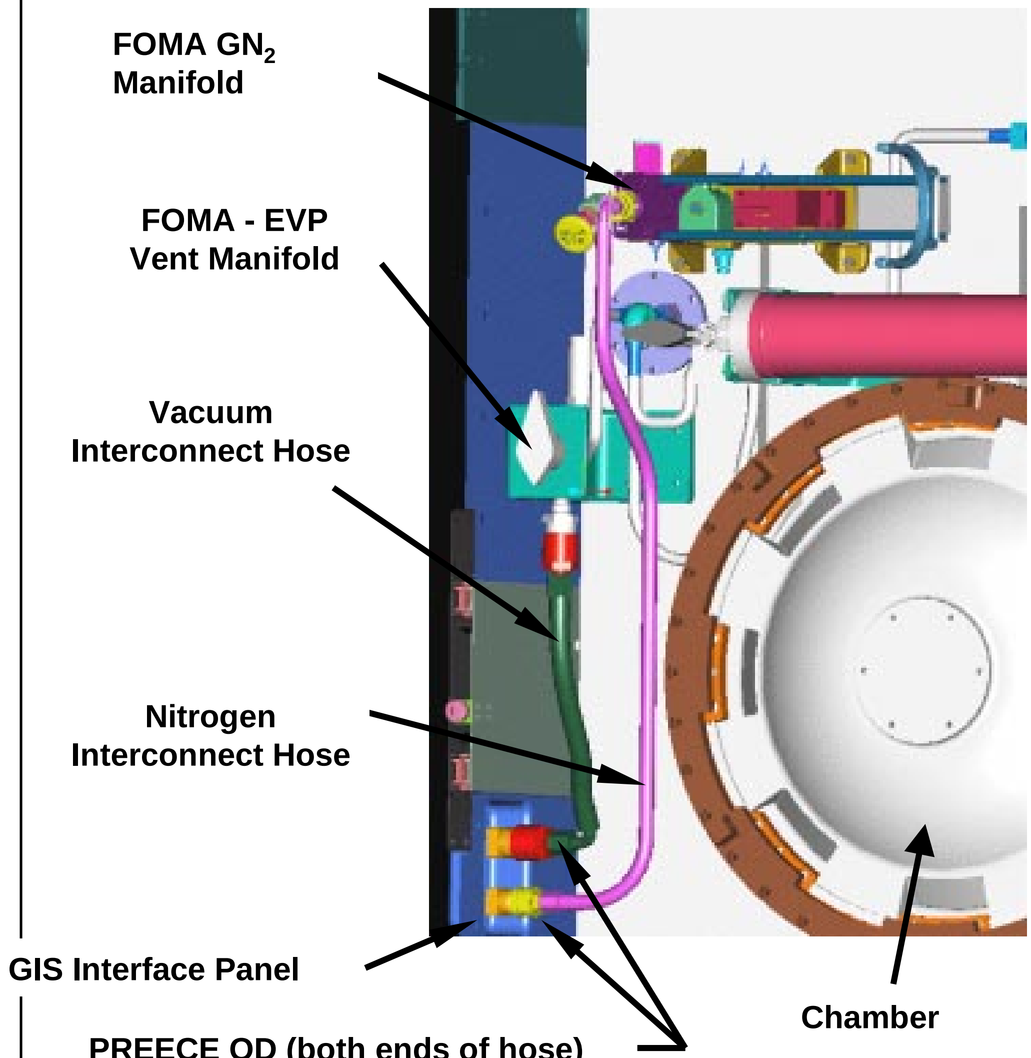
Features:

VES

- used for bulk gas removal.
- access provided by ISS controlled valve
- access provided to one user at a time

VRS

- used for maintaining long duration vacuum with
- minimal flow rates
- access provided by manual valve
- access provided to one to six users at a time
- requires systems be evacuated prior to use



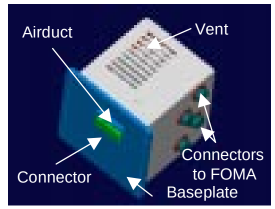
CIR Avionics

Tim Ruffner

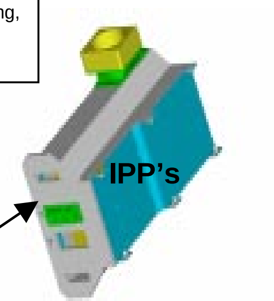
Scott Lawyer

CIR Avionics Major Subsystems

The **PI Avionics Package** provides a common processor, memory, and data acquisition interfaces for PI hardware mounted in the combustion chamber.

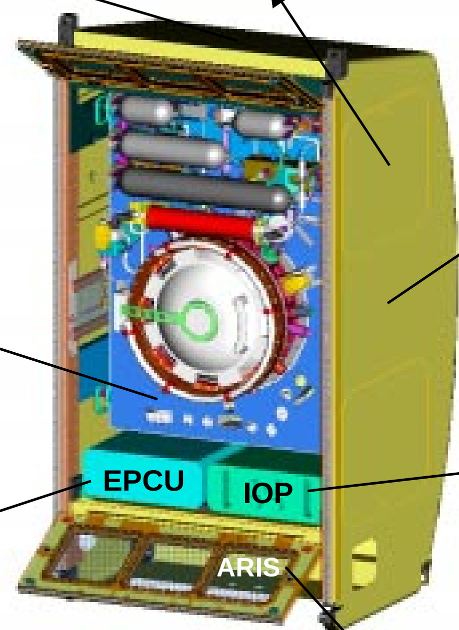


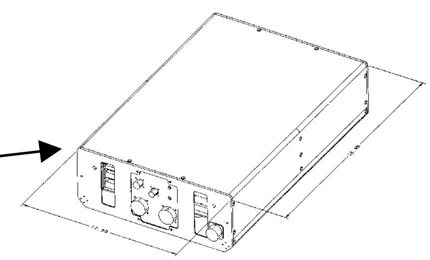
The **FCU** performs command processing, data acquisition, control, and data processing for the FOMA.



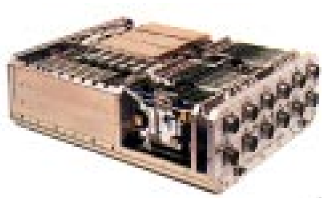
The **IPP's** perform image data acquisition, data storage, data processing, data transmission to IOP for downlink and camera control functions.

The **SAMS Triaxial Head** measures the rack microgravity acceleration environment.



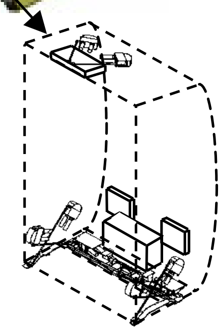


The **IOP** performs rack-level control, data acquisition, data processing, data storage, caution and warning, health and status monitoring and time synchronization.



The **EPCU** performs electrical power distribution, conversion, control, management and fault protection functions.

The SSC provides the crew interface for control and operation of the CIR and its Experiments.



The ARIS provides rack level attenuation of on orbit low frequency (<10Hz) mechanical vibrations transmitted to ISS while science operation are being conducted.

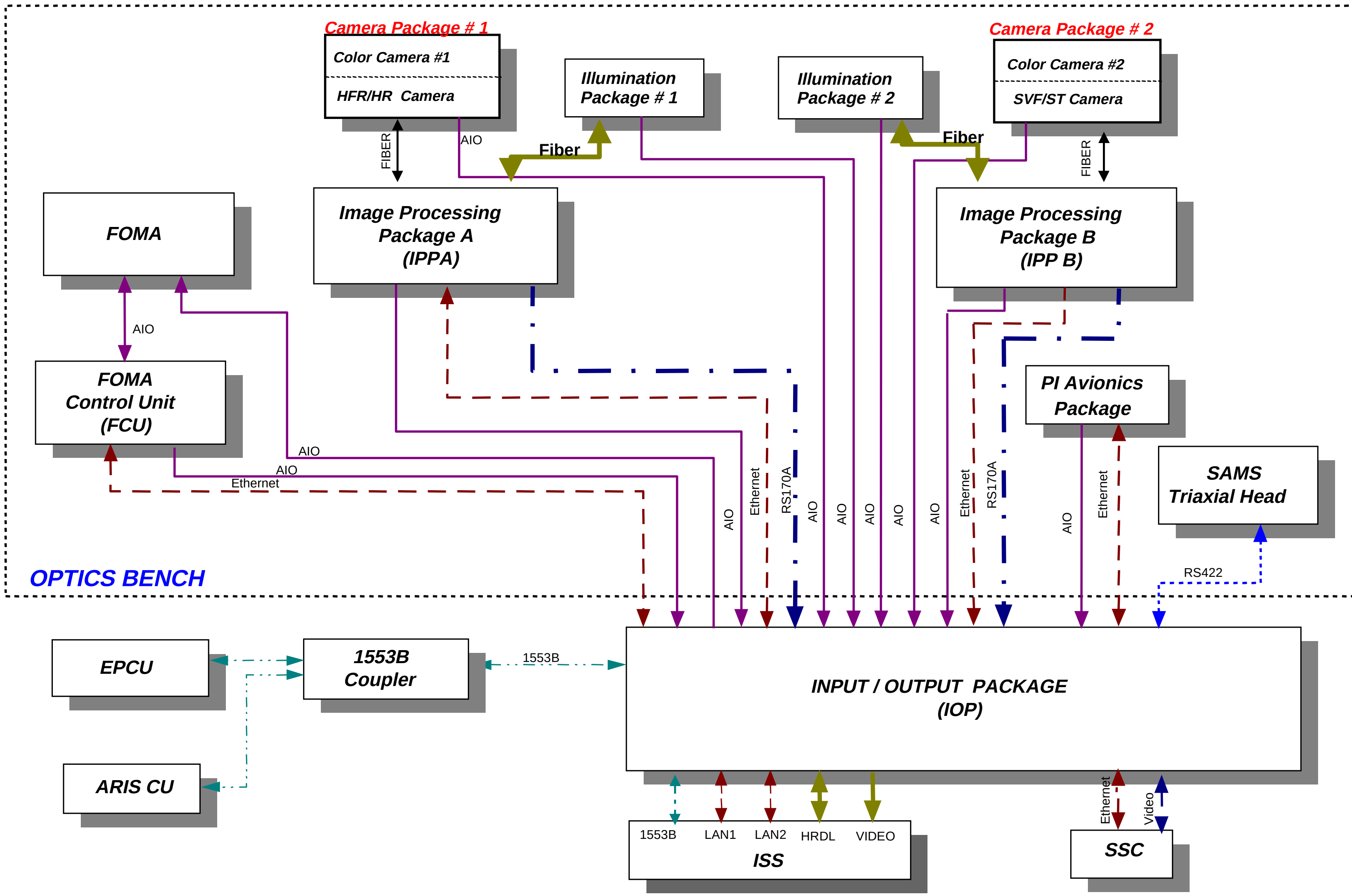
CIR Avionics Summary Table

PACKAGE	Development Status	Mass (Kg.)	Dimensions (inches)	Power (Watts)	ORU Level
I. Input/Output Processor (IOP)	**1.** EM in development **2.** 1553B Communication Interface has been tested with STEP and EPCU. **3** End-end test using EWT has been demonstrated for gas blending **4.** Preliminary thermal analysis complete	34.84	17.50" (W) x 7.00"(H) x 26.48" (D)	155	Board
II. Electrical Power Conversion Unit (EPCU)	**1.** Engineering Model has been developed. **2.** EMI test has been conducted. **3.** Vibration test has been conducted.	57.77	17.5" (W) x 6.75" (H) x 21.175" (D)	261	Package
III. Image Processing Package A	**1.** SBC and image processing boards for EM have been selected and procured. **2.** SCSI disk drives and PMC controllers for EM have been tentatively selected. **3.** Breadboard software to operate HFR/HR and HiBMs diagnostic packages has been developed and tested. **4.** Breadboard fiberoptic interface for digital image data has been design and tested. **5.** Breadboard design for direct camera to disk interface is in development. **6.** Software requirements have been documented.	21.5	16.04"(W) x 8.25" (H) x 22.1" (D)	410	Board
IV. Image Processing Package B	Same as for package A.	21.5	16.04"(W) x 8.25" (H) x 22.1" (D)	410	Board
V. FOMA Control Unit (FCU)	**1.** EM design in progress **2.** Electrical hardware identified and procured. Electrical design 80% complete. **3.** Enclosure design 50% complete. **4.** Software output drivers 90% complete; data acquisition 20% complete; Corba interface complete. **5.** Gas blending has been successfully performed using embedded software and hardware.	10.32	11.4" (W) x 11.4" (H) x 12.2" (D)	168	Board
VI. SAMS Triaxial Head	Flight TSH built; Comm. I/F with IOP in development			2	Package
VII. PI Avionics Package	Conceptual design	10.32	9.84" (W) x 16.7" (H) x 9.84" (D)	200	Package
VIII. Station Support Computer (SSC)	N/A		N/A		N/A
IX. ARIS CU	N/A		N/A		N/A

CIR AVIONICS CAPABILITIES and OPERATIONS CONCEPT

- Communications with all ISS C&DH interfaces via Input/Output Package(IOP)
  - High Rate Data Link for post-test digital image transfer
  - Medium Rate Data Link(Ethernet LAN1 and LAN2) for real-time data transfer of SAMS and ancillary data
  - Health/Status and Commanding via 1553B
  - Real-time analog video via Common Video Interface Transmitter
- Rack-level health/status monitoring and caution/warning functions via IOP
- Power distribution, conversion, control, and fault protection via Electrical Power Control Unit (EPCU)
- Data mass storage of 80+ GB prior to downlink
- Embedded Web Technology for crew display providing internet-like connection to all FCF science, health and status and command screens
- PI Avionics Package used for data acquisition and control of a class of experiments
- Commercial-off-the-Shelf electronics (COTS) used extensively to leverage cost and performance
- Image Processing Packages (IPPs) acquire camera data and store images locally for post-test downlink

CIR AVIONICS FUNCTIONAL INTERFACES



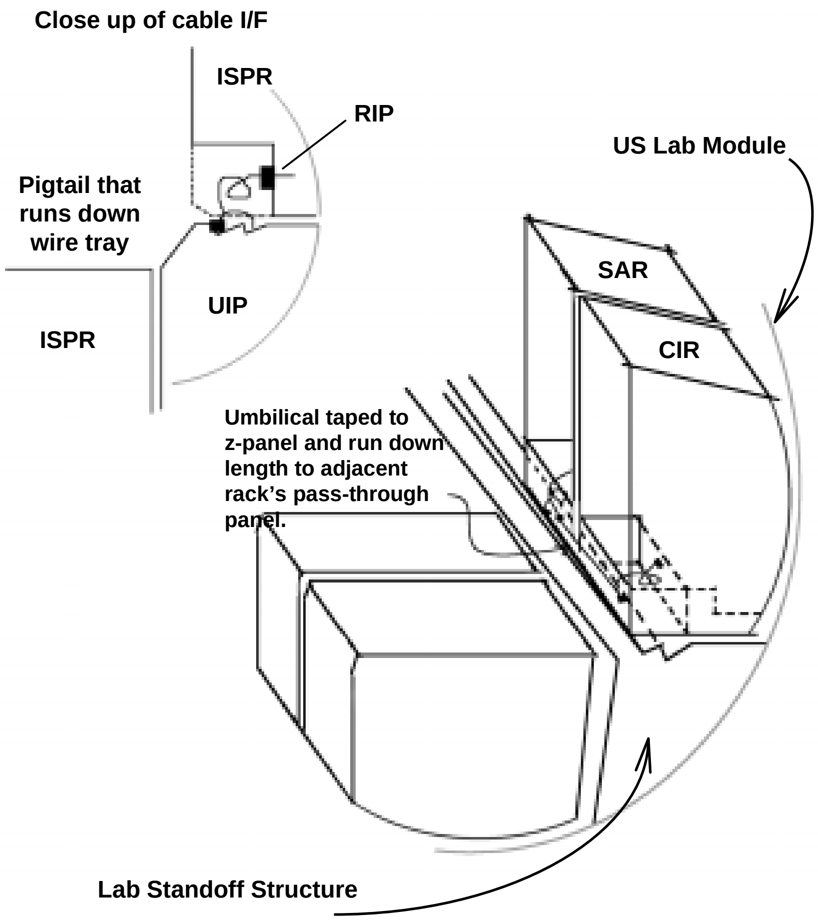
ISS Fluids and Combustion Facility - RACK-to-RACK CONNECTIONS

Rack to Rack Umbilical Concept

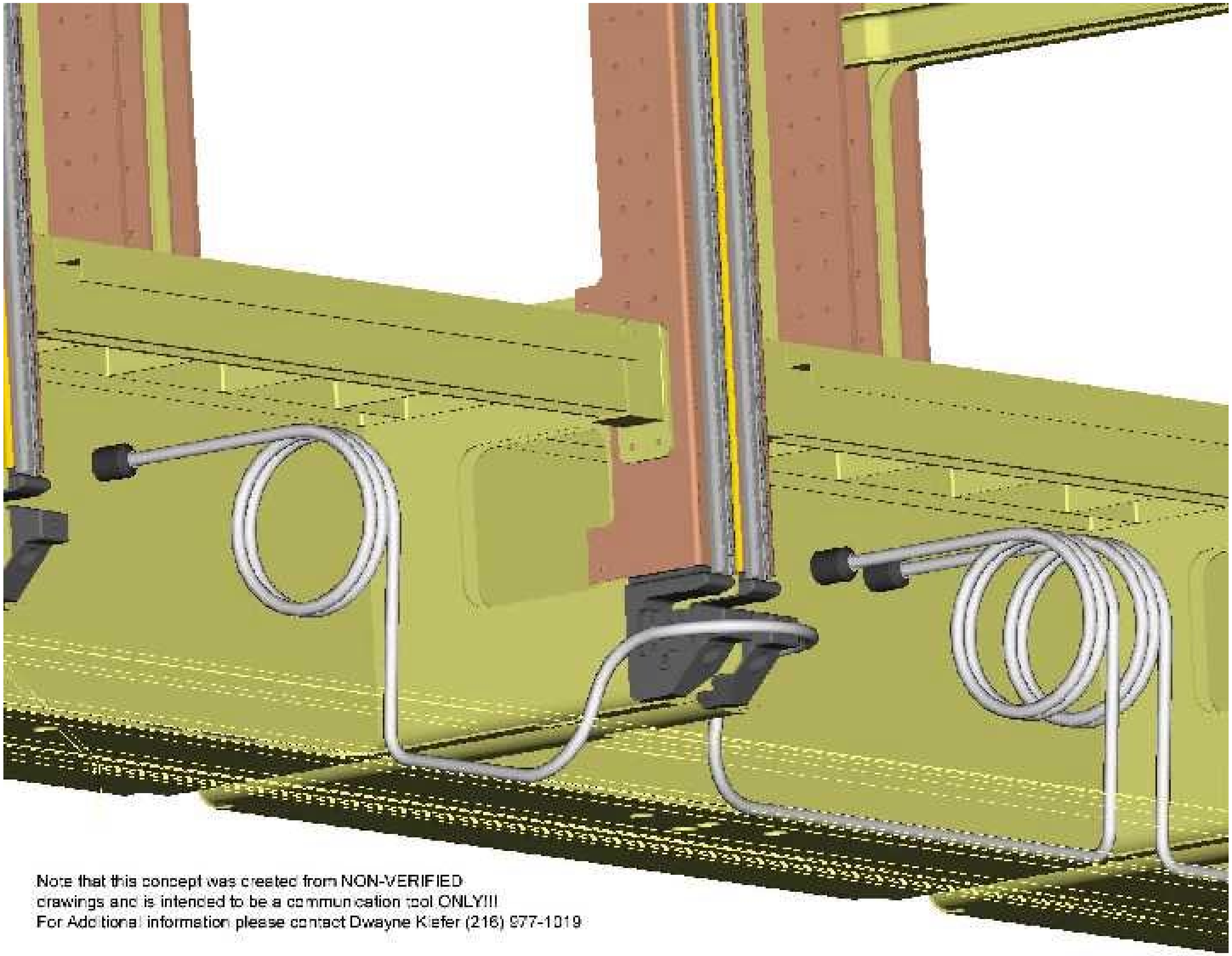
- ✓ Fiber optic cable bundle routed from SAR to each science rack along z-panel.
- ✓ Connectors added to ARIS pass through panel at each rack.
- ✓ FCF diagnostic capabilities are accessible to non-FCF payloads via connectors on SAR, CIR, FIR pass-through panels.
- ✓ Allows high-speed data transfer between racks independent of ISS C & DH system.

Rack to Rack Umbilical Benefits

- ✓ Provides flexibility to off-load hardware from optics plates in CIR and FIR to create space for PI-specific equipment.
- ✓ Alleviates burden on CIR and FIR ECS to cool electronics.
- ✓ Provides opportunity to view CIR chamber from 8 window locations.
- ✓ Enables simultaneous operation of high-resolution, high frame rate cameras in FIR.
- ✓ Provides greater number of test runs without downlink resource available.



RACK-RACK UMBILICAL CONCEPT

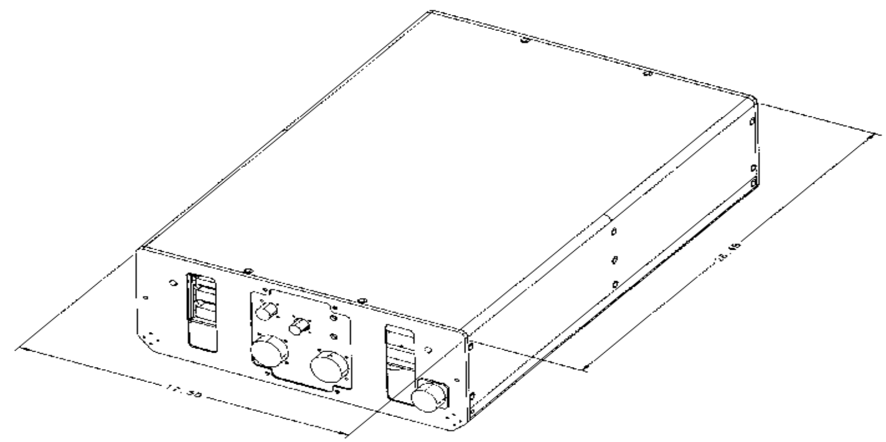


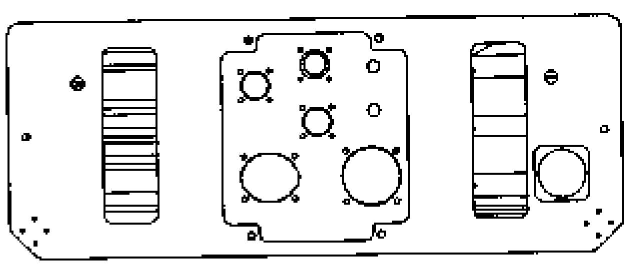
Note that this concept was created from NON-VERIFIED drawings and is intended to be a communication tool ONLY!!!
For Additional information please contact Dwayne Kiefer (216) 977-1019

CIR IOP REQUIREMENTS and DESIGN FEATURES

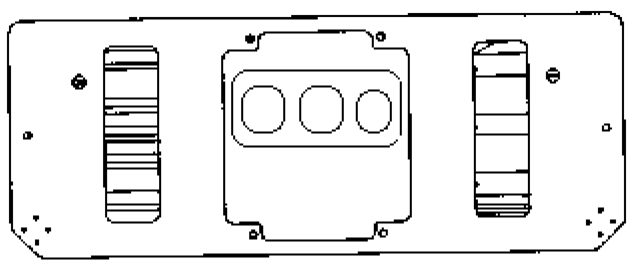
FUNCTIONAL REQUIREMENTS

- ✓ Monitor health and status data of all CIR subsystems.
- ✓ Provide overall rack command and control.
- ✓ Provide interfaces to ISS video, 1553B, ethernet, and fiber optic data services.
- ✓ Generate caution and warning messages for distribution and display to the on-board crew and to the ground.
- ✓ Accept and execute commands received by the crew via the SSC or by the ground via 1553B.
- ✓ Provide time stamping of health/status data and time synchronization services for all CIR processors based upon ISS time signal.
- ✓ Provide data buffering prior to downlink.





FRONT PANEL

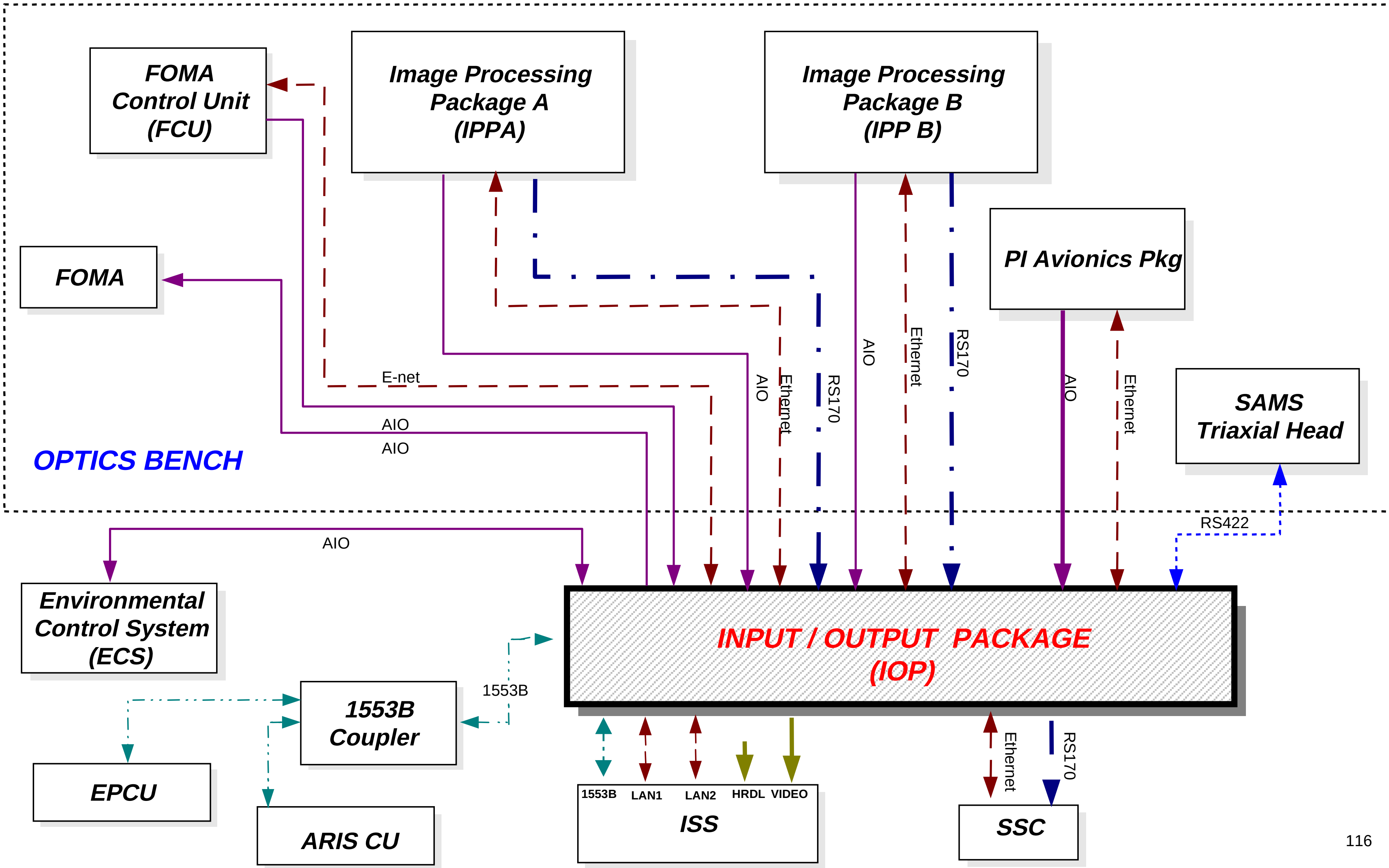


BACK PANEL

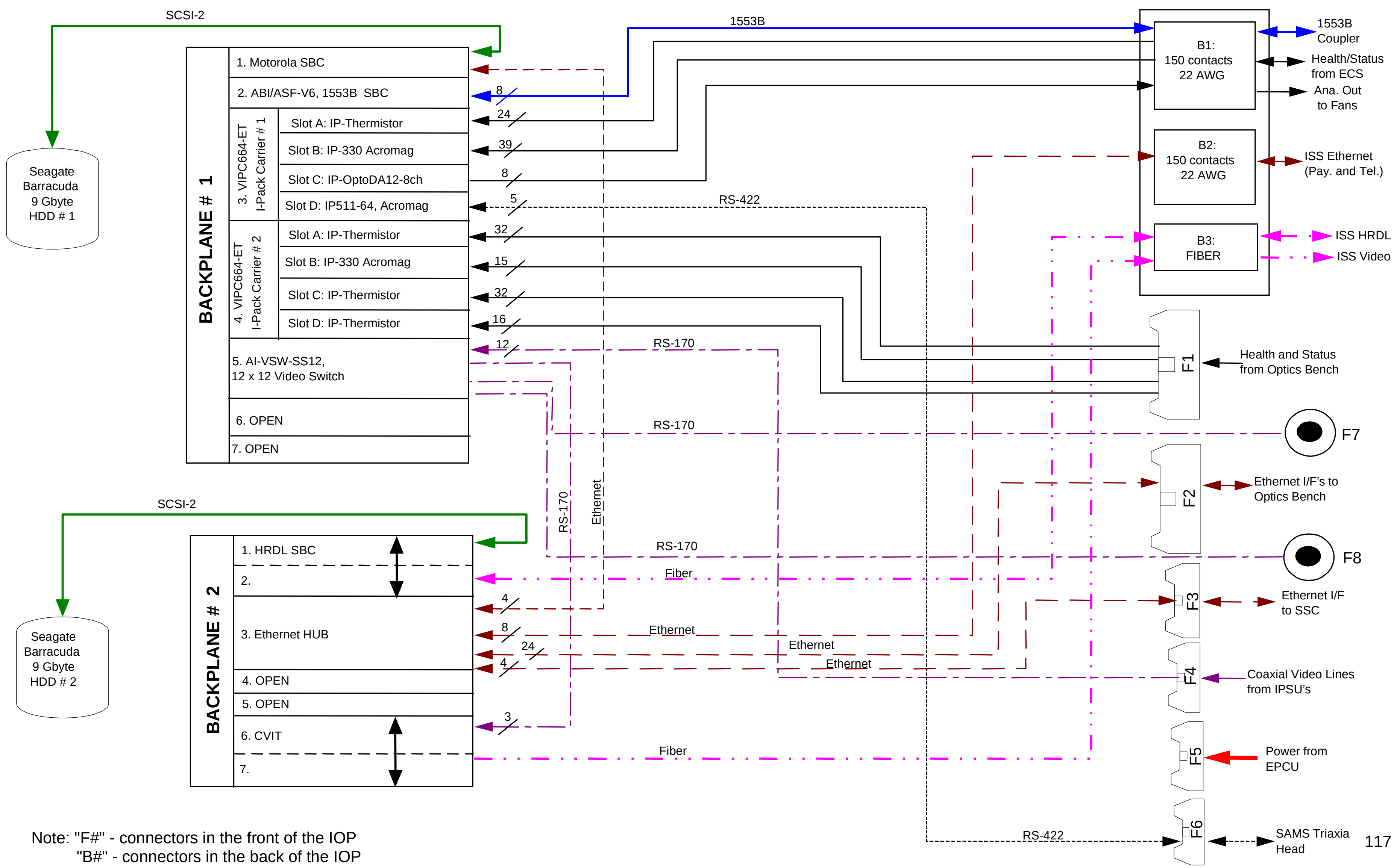
DESIGN FEATURES

- ✓ **COTS air-cooled electronics using proven industry standards**
  - ✓ **VME64x architecture (6U form factor)**
  - ✓ **Industry Pack carrier boards for Analog I/O modules**
  - ✓ **PPC603e processor running VxWorks OS**
  - ✓ **9 GB hard disk drives for data buffering and storage**
- ✓ **MSFC-provided electronics for two ISS interfaces**
  - ✓ **High Rate Data Link board**
  - ✓ **Common Video Interface Transmitter**
- ✓ **Front-panel interfaces (38999 connectors)**
  - ✓ **Optics bench I/O and communications**
  - ✓ **Power from EPCU**
  - ✓ **Station Support Computer**
- ✓ **Rear-panel interfaces (ARINC connector)**
  - ✓ **EPCU, ARIS CU, and ECS I/O and control**
  - ✓ **ISS interfaces**

CIR IOP EXTERNAL INTERFACES



CIR IOP INTERNAL INTERFACES



Note: "F#" - connectors in the front of the IOP
"B#" - connectors in the back of the IOP

CIR IOP ELECTRICAL CONNECTIONS - SUMMARY

	F1	F2	F3	F4	F5	F6	F7	F8	B1	B2	B3
Thermistor Channels	40	0	0	0	0	0	0	0	12	0	0
Analog Output Channels	0	0	0	0	0	0	0	0	4	0	0
Analog Input Channels (22 AWG)	5	0	0	0	0	0	0	0	0	0	13
RS 422 Interface	0	0	0	0	0	1	0	0	0	0	0
Ethernet Interface	0	6	1	0	0	0	0	0	2	0	0
MIL-C-1553B Interface	0	0	0	0	0	0	0	0	1	0	0
Fiber Optic	0	0	0	0	0	0	0	0	0	0	2
Analog Video Channels (RS 170)	0	0	0	4	0	0	1	1	0	0	0
4A, 28V Power circuits	0	0	0	0	2	0	0	0	0	0	0

Notes: The numbers shown in the table represents the number of channels.
"F#" - represents connectors in the Front of the IOP.
"B#" - represents connectors in the Back of the IOP.

Legend:

F1- 38999, 128 contacts, size 22 AWG
F2- 38999, 128 contacts, size 22 AWG
F3- 38999, 13 contacts, size 22 AWG (for SSC)
F4-38999, 6 contacts, coax. (for video signal for IPSU's)
F5- 38999, 16 contacts, 16 AWG (PWR)
F6 - 38999, 8 contacts, size 20AWG and 4 contacts, size 16AWG (for SAMS TSH)
F7 and F8 - BNC Connectors
B1- 150 contacts, 22 AWG (Part of a 3-bay ARINC connector)
B2 - 150 contacts, 22 AWG (part of a 3-bay ARINC connector)
B3 - 2 Fiber contacts (part of a 3-bay ARINC Connector)

CIR Optics Bench Harnessing Design

Requirement

- Provide electrical interfaces to combustion experiment hardware
  - Allow for easy system reconfiguration

Description

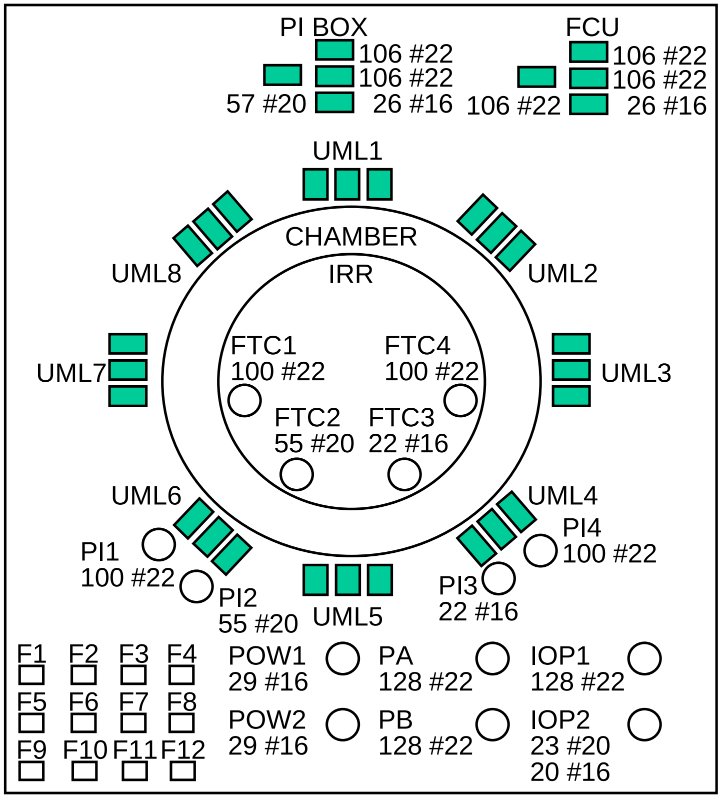
- Electronics plug into standard interface on back of optics bench. Harness internal to optics bench routes to connectors on front of bench for system interconnections.

Specifications/Features

- Universal mounting locations (UMLs) provide standard electrical connection points for diagnostic packages and IPPs
  - UMLs allow easy relocation of IPPs and diagnostic packages
  - All harnessing from UMLs internal to optics plate
- Even numbered UMLs contain 6 fiber optics, 1 four to eight amp power circuit, 1 ethernet, 2 thermistors, 1 coax, and 32 PI specific #22 gage lines
  - Double these numbers for odd UMLs except PI lines
- IPPs can be located at odd UMLs, diagnostics at all UMLs
- Fiber optics used for all diagnostic package data and control signals
  - Reconfigurable fiber optic jumpers connect IPPs and diagnostic packages in any UML
  - Easy connection from IPP in SAR to diagnostic at any UML
- Reconfigurable jumpers allow communication from PI specific location to the chamber, any UML, or the IOP with 22, 20, and 16 gage wire or with single mode or multimode fiber optics (single mode fiber into chamber only)
- Paralleling 4A, 28Vdc power circuits in harness between the EPCU and the optics bench allows power level adjustment to any location
- Power into chamber can be routed through the PI specific box or directly from the EPCU

Development Status/Test Results

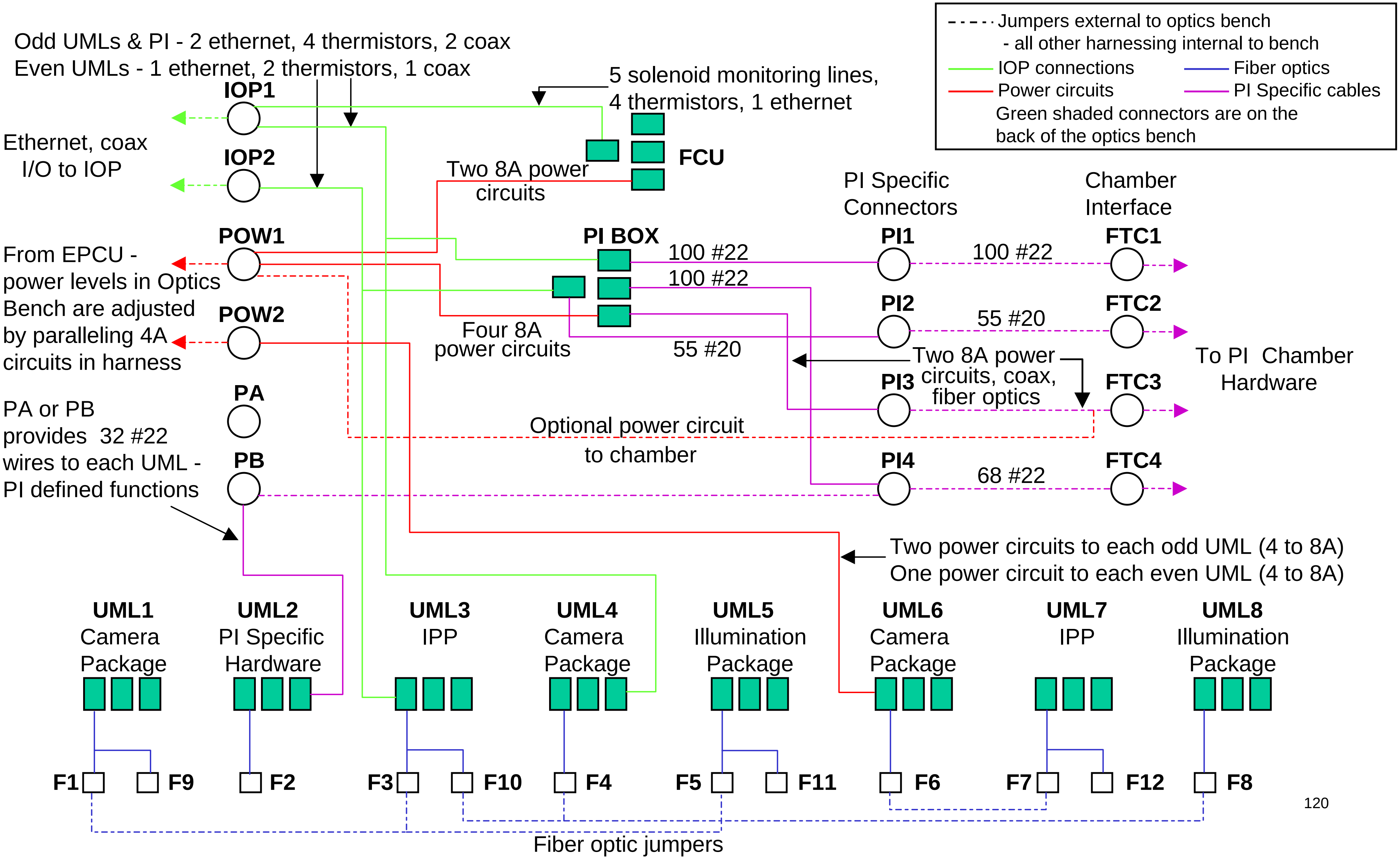
- Harnessing fit check with full optics bench stereo lithography model completed
- Initial draft of EM harnessing drawings completed
- MTP fiber optic connectors space qualified by GSFC
- Analex internal harness review completed



Optics bench relative connector locations

ARINC 404
MIL-C-38999
Green shaded connectors on back of optics plate
MTP fiber optic

CIR OPTICS BENCH INTERCONNECTION Example



PI AVIONICS PACKAGE

Philosophy:

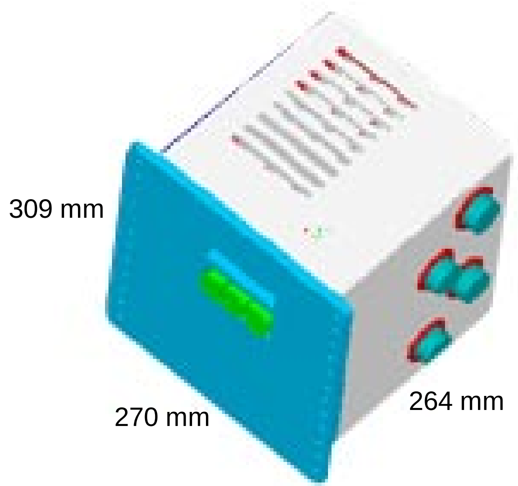
• Allow independent development of PI specific apparatus in a low cost environment.

• Access to cutting-edge commercial technologies.

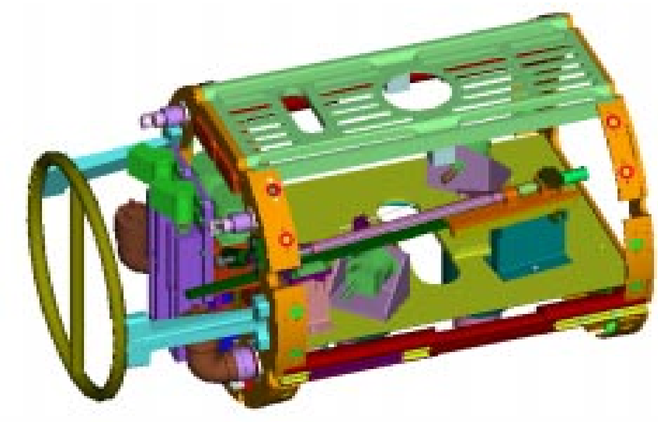
Function:

• Provide tight, closed-loop control of PI specific equipment.

• Provide data acquisition and signal conditioning for PI specific diagnostics.



• DATA
• CONTROL
• POWER



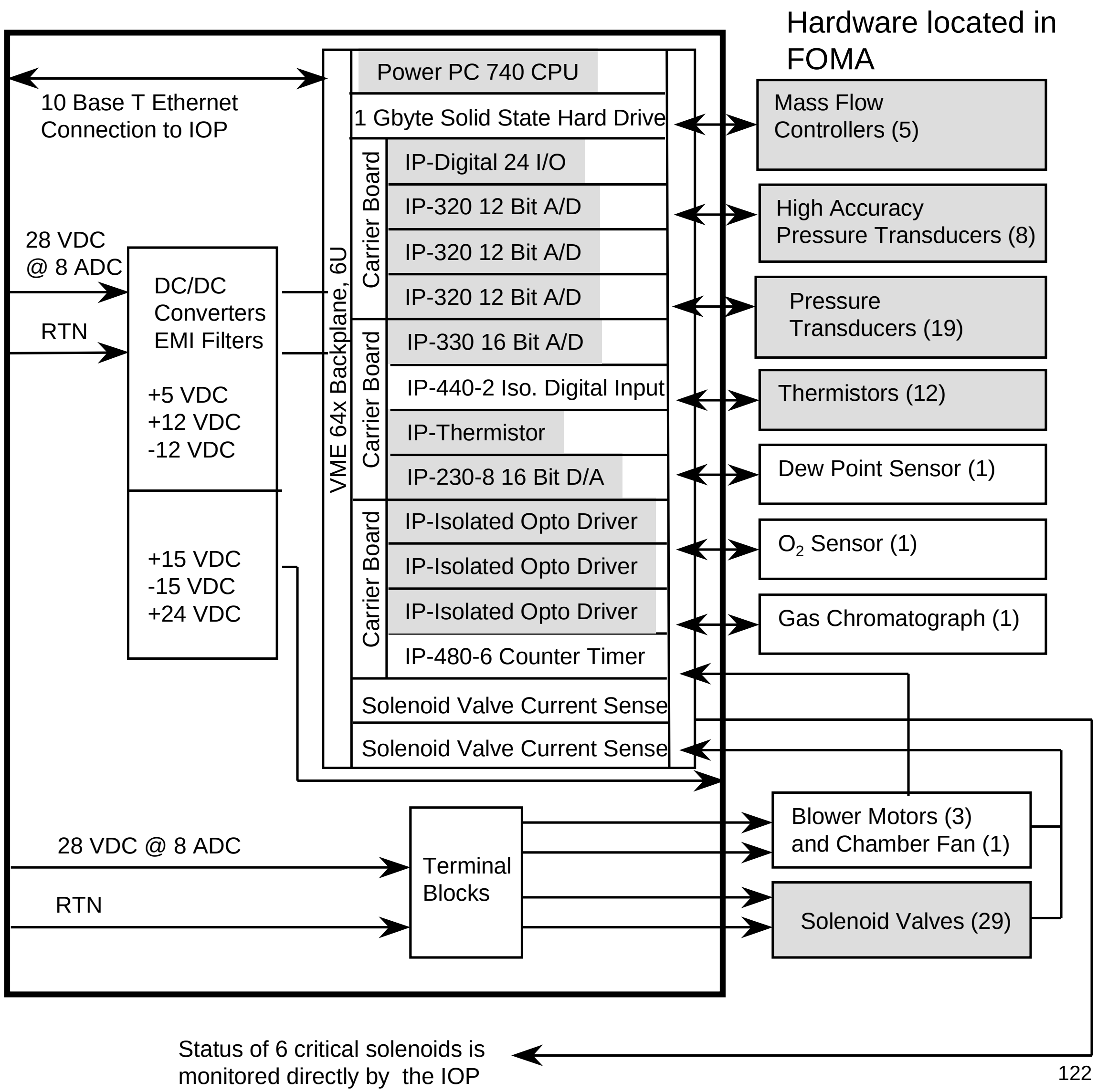
Design Approach

Design for class of experiments (i.e. droplet combustion), using primarily commercial hardware to minimize cost and schedule. Provide "hooks" for future users such as Univeral Serial Bus (USB) and a variety of I/O channels.

FOMA CONTROL UNIT

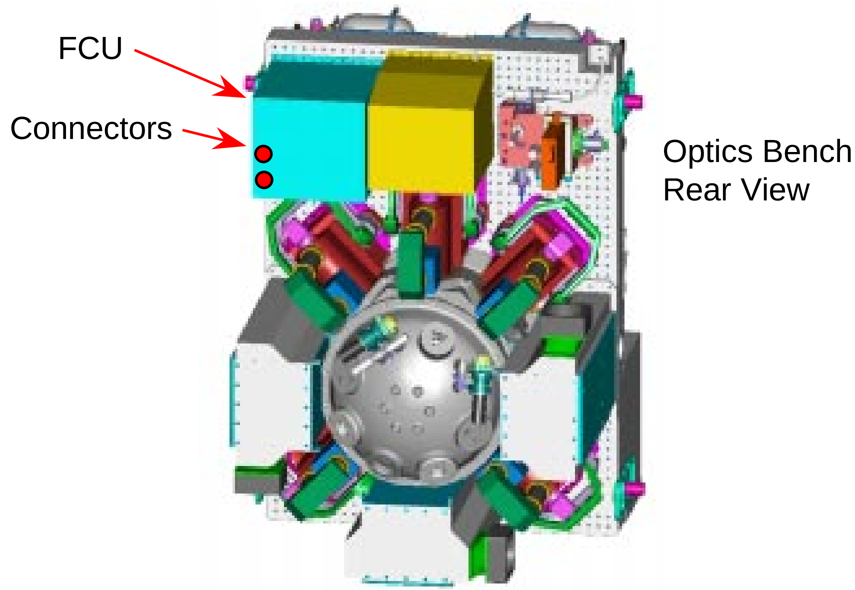
Functional Capabilities

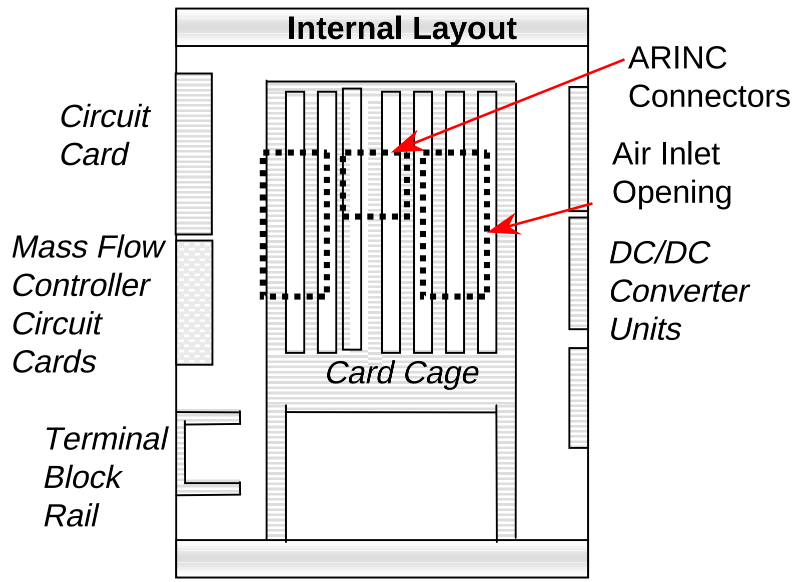
- Provide gas blending via two Methods.
  - Partial Pressure
  - Dynamic
- Provide gas flow through capabilities.
- Safely exhaust chamber gases.
- Monitor and store all pressures, temperatures, and mass flow rates within the FOMA during gas blending and experiment operation. Nominal 1 Hz acquisition rate.
- Control gas chromatograph for chamber sampling.
- Provide FOMA hardware status to the IOP for transmittal to the ground.
- Safety monitoring of temperature, pressure, flow rates, and valve positions to ensure safe operation of the FOMA.
- Embedded breadboard consisting of highlighted hardware has been used to successfully blend gas using Dynamic and Partial Pressure methods.



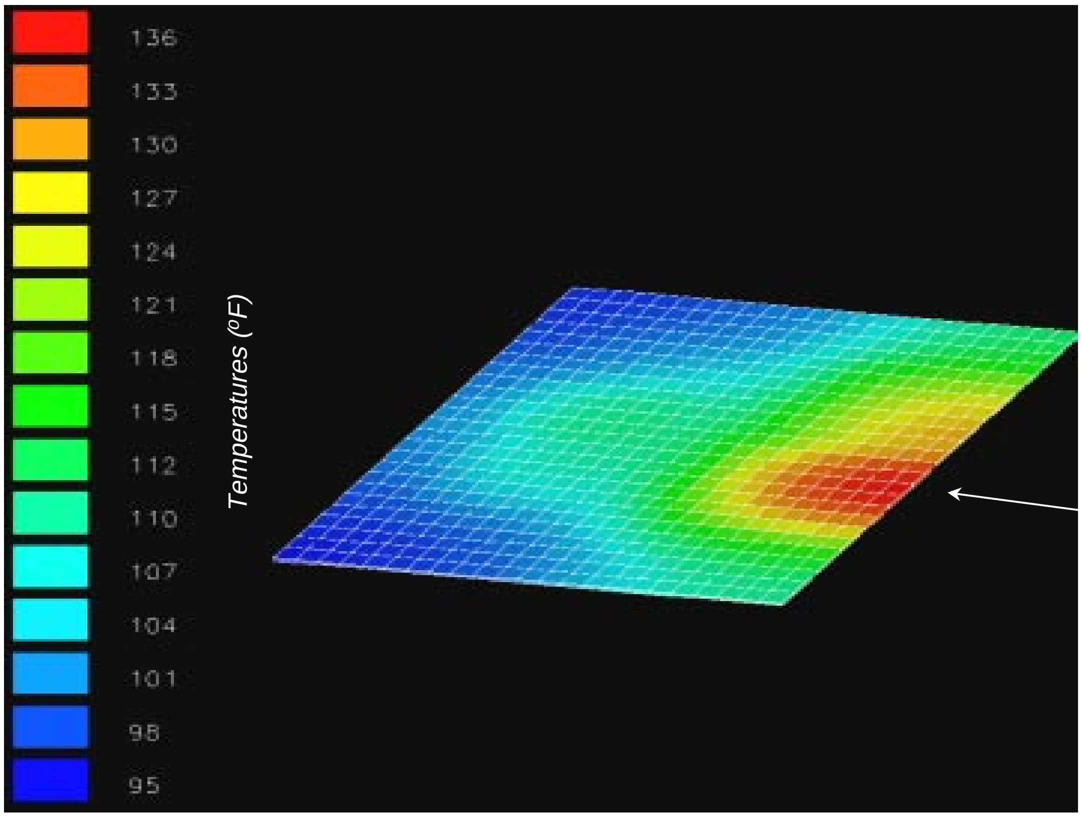
Functional Capabilities Continued

- FCU mounts on the back side of the optics bench next to the PI Avionics box.
- Electrical connections to FOMA hardware located on the front of the optics bench are accomplished through the bench via ARINC connectors.
- Electrical connections to FOMA hardware located on the back of the optics bench are accomplished via panel connectors on the FCU wall.
- FCU/FOMA power consumption is 331 Watts
- Chamber Pressure Accuracy ± 0.01 PSIA.
- Chamber Temperature Accuracy ± 0.1 °C.
- Mass Flow Controller Flow Rate Accuracy ±1.0% full scale range.
- Hardware packaging concept defined, mechanical design in work.
- Electrical design concept defined, generation of wiring and schematic diagrams in work.
- All electronic hardware required to complete a functional FCU has been procured.





FOMA Control Unit Wall Temperature Containing DC/DC Converters Thermal Analysis

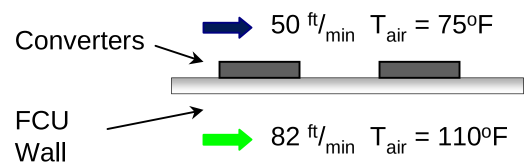


Converter Heat Dissipation

AB100S	23.47 W
AB35D/12	1.68 W
AB50S	12.5 W
AB35D/15	7.5 W
AB20S	4.48 W
Total	**49.63 W**

Analysis Schematic

(FCU Interior Flow 5.7 CFM)



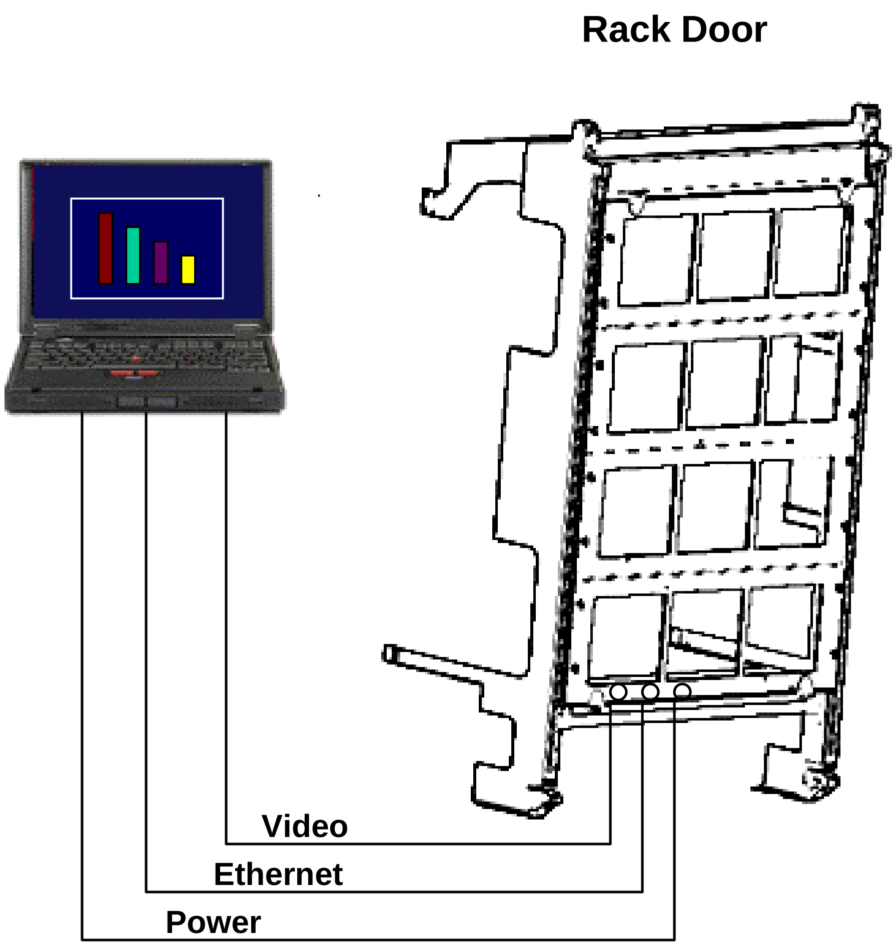
(FCU Exterior Flow 22 CFM)

Maximum Analyzed Surface Temp. = 136ºF

Cool down time from 136ºF to touch temperature 113ºF is less than 1 minute based on air inlet temperature of 75ºF.

Cool down time from 136ºF to touch temperature 113ºF is less than 2 minutes based on air inlet temperature of 97ºF.

STATION SUPPORT COMPUTER



FUNCTION

Provides the crew interface for commanding, control and health and status monitoring of the CIR during operations. Also may be used to display analog video from CIR cameras.

SSC DESIGN FEATURES

- ✓ IBM Thinkpad 760 XD (Model 9546U9E)
- ✓ 3 GB HDD
- ✓ 64 MB RAM
- ✓ Windows NT 4.0 OS
- ✓ Internet Browser (Internet Explorer)

CIR INTERFACES

- ✓ Power provided to rack door via EPCU
- ✓ Ethernet provided to rack door via IOP
- ✓ Umbilical service loops will allow door to open with internal connections made

CIR AVIONICS: IONIZING RADIATION Assessment

FCF DESIGN REQUIREMENTS & PHILOSOPHY

- ✓ SSP 57000 requires that FCF subsystems be designed to operate safely when subject to Single Event Effects and exposed to the radiation environment specified in SSP 30512.
- ✓ Project philosophy is to leverage the performance and overall value afforded by COTS electronics while accepting some science data loss due to SEEs (5% or one test point, whichever is greater)
- ✓ Avionics will be upgraded with new technology every 2-3 years

TECHNOLOGY SUSCEPTIBILITIES - EXAMPLES

Relative Risk Categories for Proton Induced Latch Up

Risk	Low	Medium	High
proton threshold (Me V)	25	25	25
proton cross section (cm^2)	$\leq$ 5.0E-13	$\leq$ 5.0E-11	$\leq$ 5.0E-09
proton flux (protons/cm^2/day)	1.0E+06	1.0E+06	1.0E+06
events/day	5.0E-07	5.0E-05	5.0E-03
events/10 years	1.8E-03	1.8E-01	1.8E+01

Relative Risk Categories for Cosmic Ray Induced Latch Up

Ion LET Threshold (Me V*cm^2/mg)	40	30	10
device cross section (cm^2)	1.0E-06	1.0E-05	1.0E-03
flux (particles/cm^2*day > LET)	1.0E-06	1.0E-04	1.0E-01
events/day	1.0E-12	1.0E-09	1.0E-04
events/10 years	3.7E-09	3.7E-06	3.7E-01

GSFC Assessment Conclusions*

Assessment of the environment indicates relatively benign total ionizing dose and [displacement] damage levels, even for COTS boards

Non-destructive SEE will likely be an operations issue, but can be mitigated with design approaches.

Destructive Single Event Latch-up (SEL) is the major *potential* risk for hardware survival. Risk can be better understood with board-level testing.

***Ref. *Fluid and Combustion Facility Radiation Risk Evaluation for Critical Boards*, Paul W. Marshall and Ken LaBel, (Dec. 15, 1998)**

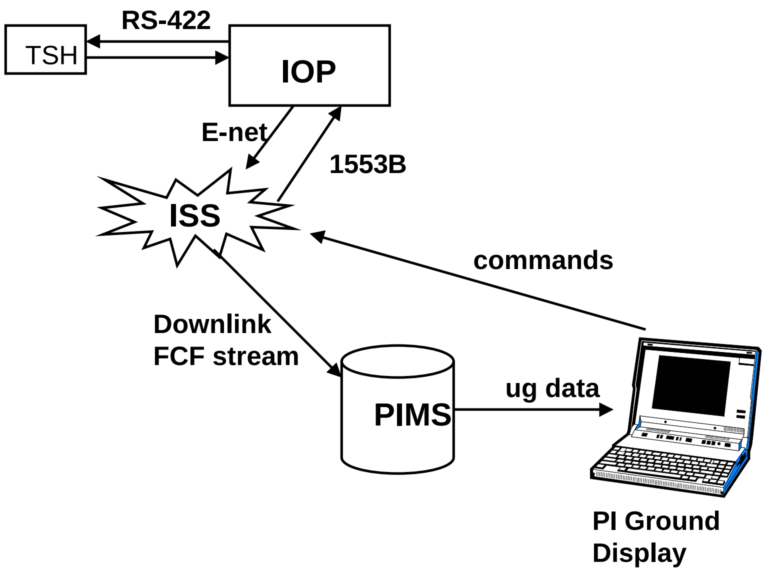
RISK MITIGATION STRATEGIES

- ✓ Implement Error Detection and Correction (EDAC) for processor memory locations (e.g. Reed-Solomon algorithm)
- ✓ Provide cold spares for all ORUs at highest risk
- ✓ Implement watchdog timing functions in software to quickly cycle power on lock-up
- ✓ Cycle power periodically and when exiting the South Atlantic Anomaly
- ✓ Procure rad-hardened and rad-tolerant hardware when available and cost-effective
- ✓ Use two-step commanding approach
- ✓ Perform board-level proton tests of high risk hardware (Indiana University or University of California at Davis)

Space Acceleration Measurement System (SAMS) in CIR

ug REQUIREMENTS

- ✓ Measure microgravity accelerations from 1.0E-06g to 1.0E-02g
- ✓ Provide three orthogonal measurements from .01Hz. to 200Hz.
- ✓ Provide measurement accuracy to within +-10% in full range.
- ✓ Data shall be made available in several formats in near-real time on the ground (ex. g versus time)
- ✓ Acquired data shall be timestamped using a common clock relative to ISS events.
- ✓ Bandwidth shall be selectable to 200Hz.



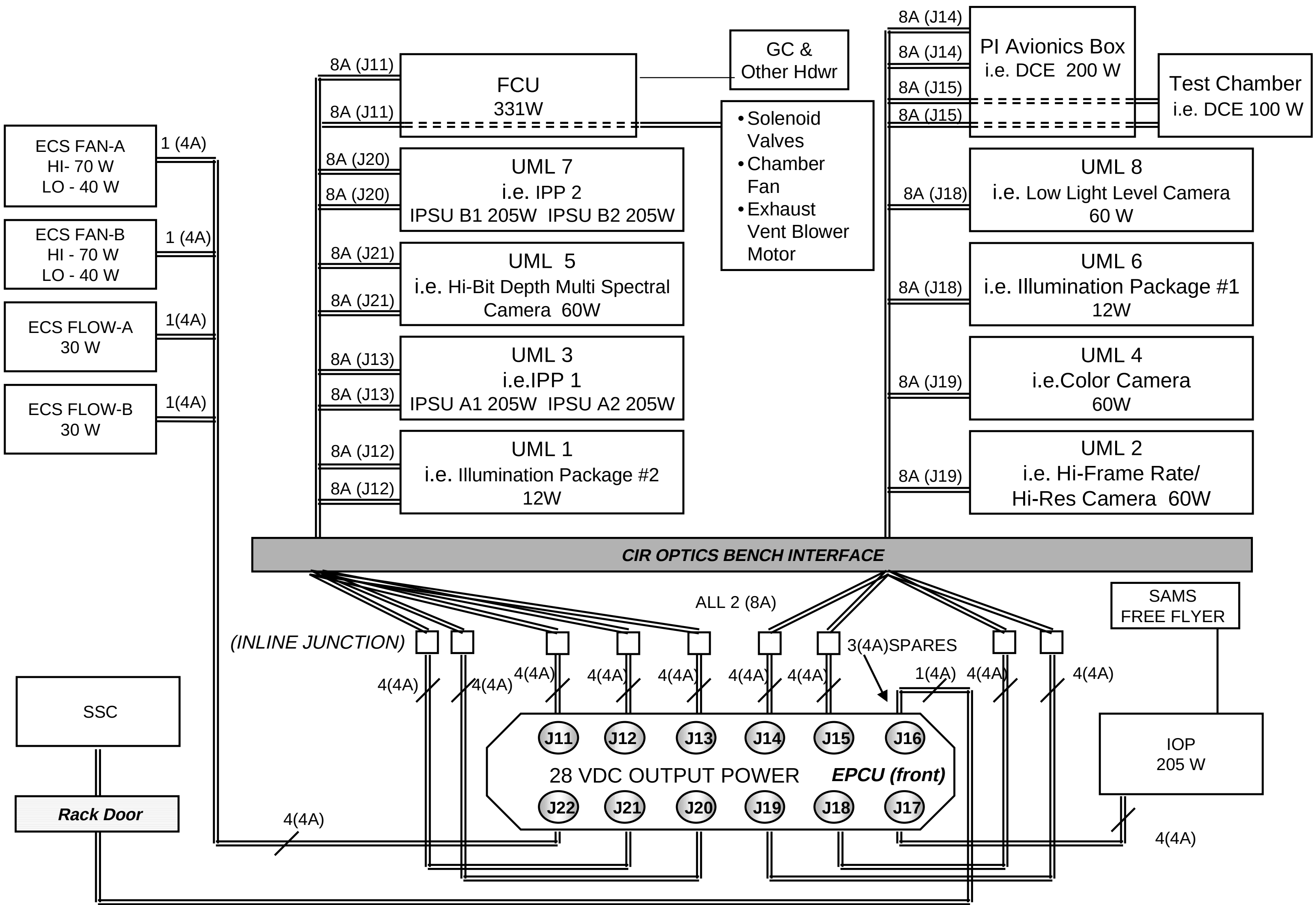
IMPLEMENTATION

- ✓ SAMS Free-Flyer Triaxial Sensor Head (TSH) mounted on front of optics bench (2.9” x 2.9” x 2.8”)
- ✓ Cable harness connects TSH to front of Input/Output Package (IOP)
- ✓ IOP provides +-15VDC power and RS-422 communications for command and data acquisition
- ✓ TSH provides three-axis measurement bandwidth between 0.01Hz. and 200 Hz.
- ✓ IOP provides data buffering, data processing, timestamping, and dowlink via ISS LAN interface as part of FCF data stream.
- ✓ Principal Investigator Microgravity Services(PIMS) strips SAMS data from FCF data stream and provides data display functions on ground

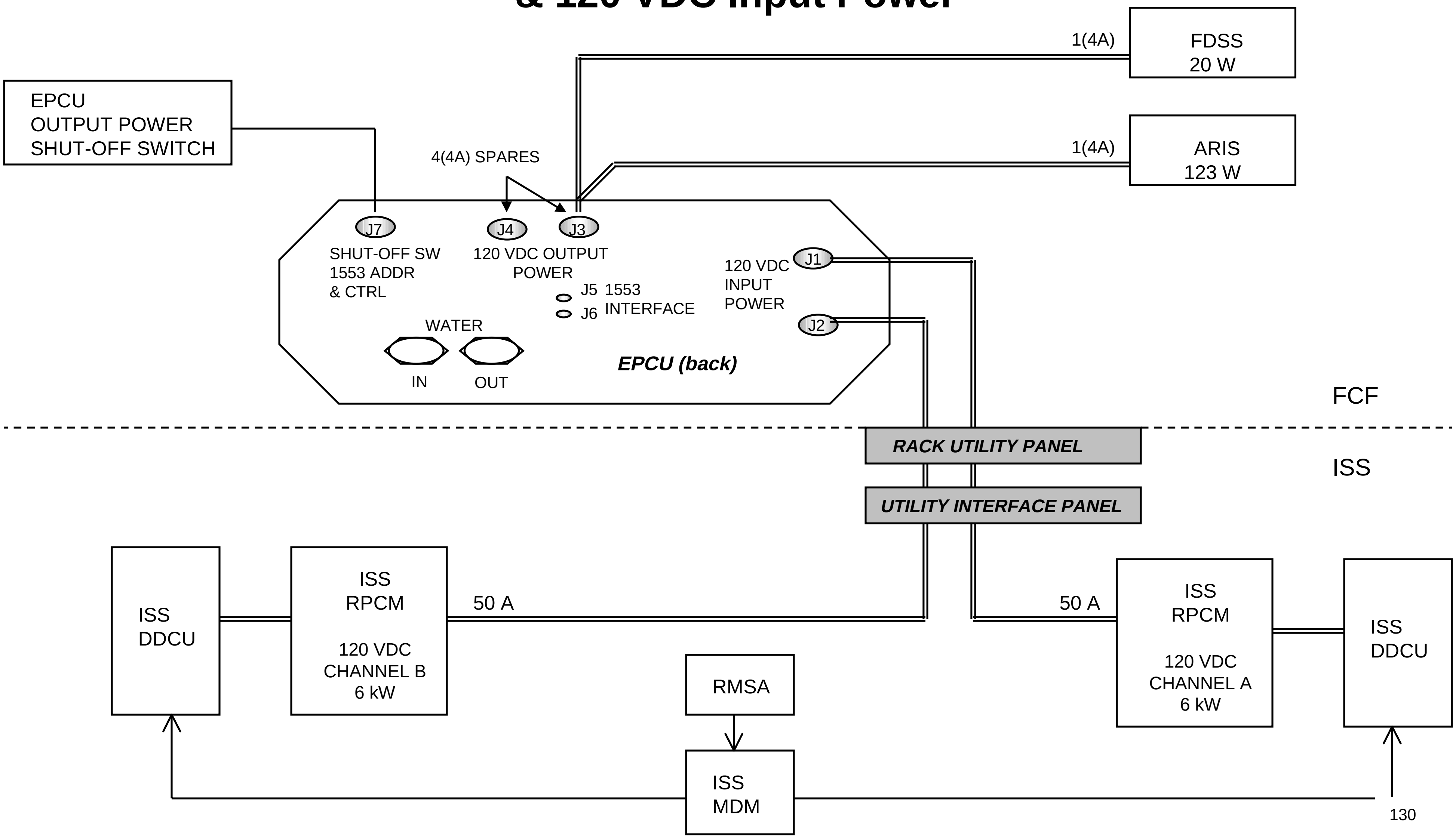
Power Distribution Summary

- Electrical Power Control Unit (EPCU) supplies power to all electrical hardware internal to the rack.
- Two 28 VDC @ 8 ADC (448 Watts) lines are available at UMLs 1, 3, 5, 7, PI Avionics Box, Chamber, and FOMA Control Unit.
- One 28 VDC @ 8 ADC (224 Watts) line is available at UMLs 2, 4, 6, and 8.
- Two 120 VDC @ 4 ADC are used for the ARIS and FDSS.
- Diagnostic packages can be relocated from one UML to another UML without having to reconfigure wiring.
- Paralleling of the EPCU 4 ADC lines occur in the power cable from the EPCU to the optics bench using Deutsch in-line junction terminals. This approach minimizes the number of power connectors required on the optics bench.
- Wire derating analysis performed using NASA Technical Memorandum 102179 as interpreted by NSTS 18798, TA-92-038 (approved in SSP 57000) to support nominal 8 ADC load on AWG #16 wire. Short circuit analysis performed based on a short circuit current of 18.4 ADC (4.6A x 4).
- All wire used for power distribution internal to the optics bench will be per MIL-W-22759/11 with a 200 °C insulation rating.
- Initial On-State feature being used for IOP, ATCS, and FDSS.
- Maximum 28 VDC output power required from EPCU to support a DCE type experiment is 2120 Watts, EPCU 28 VDC output capability is 3000 Watts.
- Maximum 120 VDC output power required from EPCU to support rack operation is 140 W, EPCU 120VDC output capability is 3000 Watts.
- Power circuits used include 45 of 48 for 28 VDC and 2 of 6 for 120 VDC.

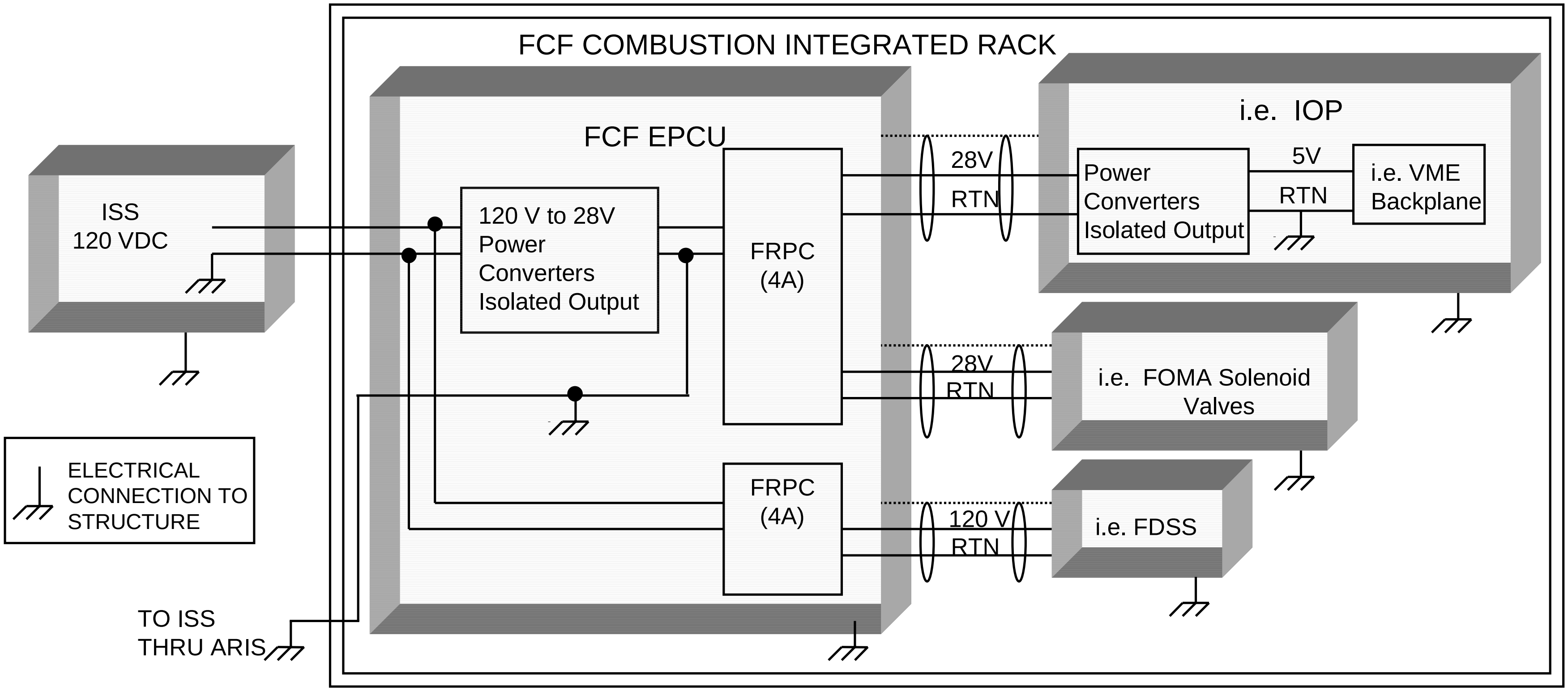
FCF Combustion Integrated Rack 28 VDC Power Distribution



FCF Combustion Integrated Rack 120 VDC Power Distribution & 120 VDC Input Power

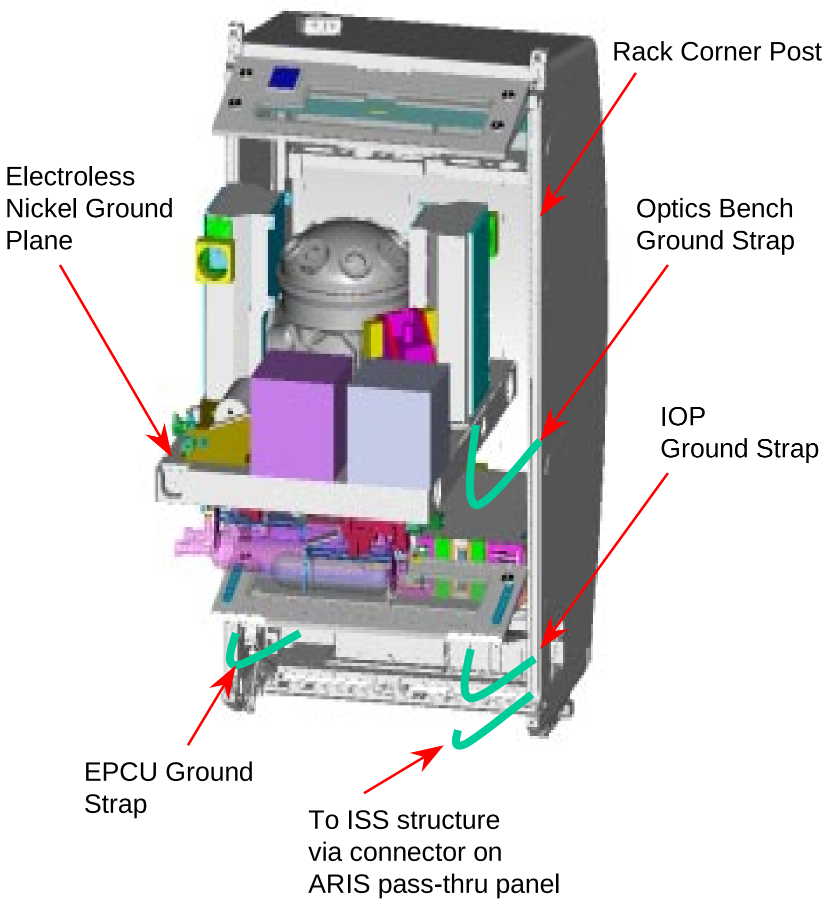


FCF Combustion Integrated Rack Electrical Grounding



- ISS Secondary power isolated from chassis
- Separately derived electrical power source connected to structure at no more than one point
- Package-to-package communication designed to eliminate ground loops utilizing fiber optics or isolated differential signals
- Wiring and cabling shall meet applicable requirements specified in SSP 30242,ISS Cable/Wire Design and Control Requirements for Electromagnetic Compatibility
- System grounding shall meet applicable requirements specified in SSP 30240, ISS Grounding Requirements

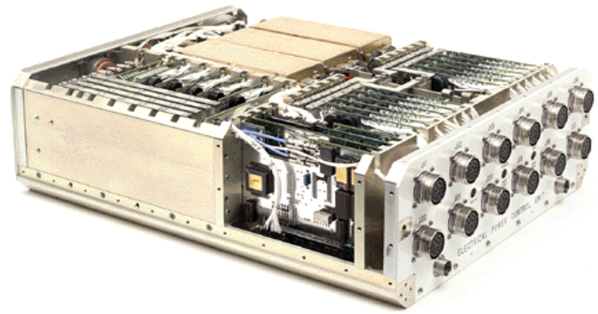
CIR Rack Bonding



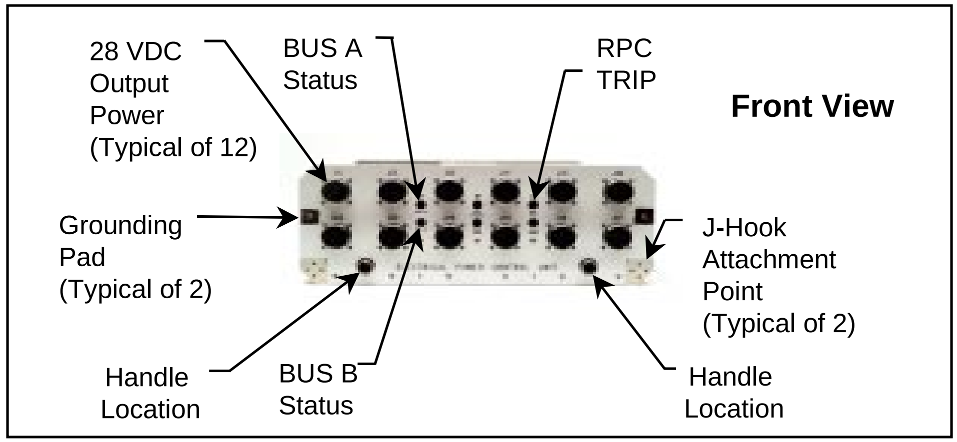
- Entire optics bench mounting surface shall be electroless nickel.
- Diagnostic package mounting surface to optics bench shall be electroless nickel.
- ARINC optics bench and diagnostic package connectors surface material shall be electroless nickel.
- Bonding strap shall be used to establish an electrical bond between the optics bench and rack per SSP 30245.
- Bonding straps shall be attached to the nickel-plated mounting locations provided on the rack corner post.
- On-orbit bond reverification of interchangeable optics bench packages will be accomplished via a visual inspection of the mating surfaces. Bonding is accomplished through mounting surfaces of the diagnostics package and the optics bench. A secondary path is through the connector shell.
- Packages separate from the optics bench such as the EPCU and IOP will utilize bonding straps attached to the rack corner post.

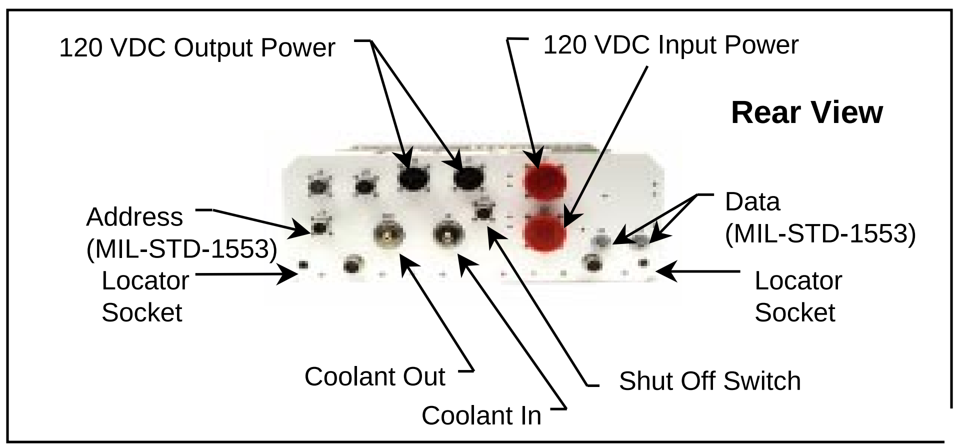
EPCU ISS Interface Requirements

- Input voltage from ISS 120 VDC nominal (116 VDC to 126 VDC) per SSP 30482 Interface B.
- Will not be damaged by specified ISS abnormal electrical transients.
- Meets ISS impedance stability requirements.
- Meets all SSP 30237 EMI requirements, except nuisance trip occurred due to Overvoltage Protection being set below CS01 Limits associated with 5V ripple injection test. Setpoint has been moved up, pass retest is expected.
- Designed to ISS Mini-Pressurized Logistic Module (MPLM) theoretical structural dynamics launch loads. EM was tested to theoretical and actual ISS MPLM launch loads and passed.
- Design Life is 10 years with 2/3 Converters, 44/48 28 VDC FRPCs, and 6/15 120 VDC FRPCs Functional;15 Year Goal.



EM EPCU





EPCU Functional Block Diagram

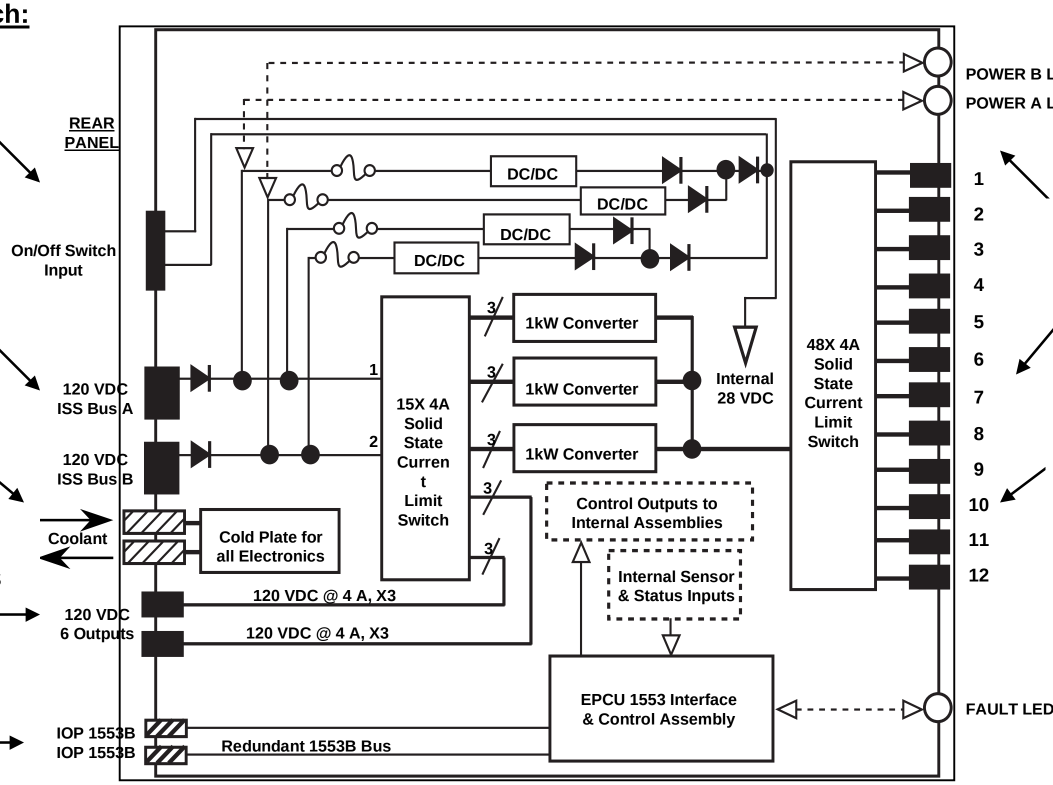
Output Power Shut-off Switch:
- Disables 28 VDC and 120 VDC output

120 VDC Power Inputs:
- Channel A 120 VDC @ 50A
- Channel B 120 VDC @ 50A
- Two Connectors

Thermal Interface:
- Water Coolant
- Two Quick Disconnects

120 VDC Power Outputs:
- 6 circuits @ 4 amps each
- 2 Rear Output Connectors, each having 3 power circuits and remote circuit configuration control pins

Command/Data Interface:
- 1553B (Redundant)
- Two Connectors



Front Panel Indicators:
- Power "ON" for Bus A and Bus B
- FRPC Overload Trip

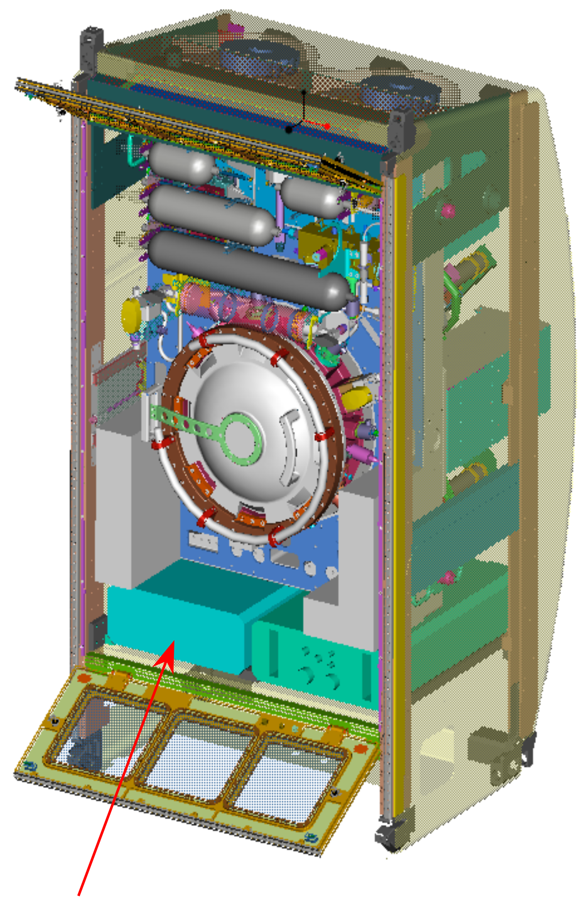
28 VDC Power Outputs:
- 3 kW Capacity (3 Converters, 1 Output Bus)
- 48 Circuits @ 4 amps each
- 12 Front Panel Output Connectors, each having 4 power circuits and remote circuit configuration control pins

FUNCTIONAL CAPABILITIES

- Channels may be paralleled to increase current capacity
- Shut-off switch will disable 28 VDC and 120 VDC output
- FRPCs Load-End Hardware Programmable to Normally OPEN or Normally CLOSED Power Up State
- FRPCs Load-End Hardware Trippable (MIL-STD-1553 Command not required)
- RMSA required to control deadfacing function
- Designed to operate in a vacuum, and thru depressurization and repressurization
- Dynamic Power Allocation
- Prioritized Load Shedding
- Parallelable FRPCs
- FRPC current limit range 4.2 to 4.6A
- Converter current limits to 150% of rated current
- Secondary power- single point ground established internal to EPCU
- Integral cold plate designed for 19.6 lbs/hr at 65 F, to 180 lbs/hr at 114 F with 0.75 PSI pressure drop max at 180 lbs/hr, at 5.88 kW out with 120 F max outlet temperature
- Dry Unit Weight 108 lbs.

Development Status

- Sundstrand delivered an engineering model of the EPCU to GRC in November 1997.
- The EM EPCU has been tested with high fidelity breadboards of the space station electrical power sub system.
- EPCU tested with DCE experiment preliminary hardware.
- EPCU Tests performed:
  - EPCU Efficiency with no 120 VDC Loads - 89% @ 3kW, 88.5% @ 1.5kW and 83% @ 600W.
  - EPCU Efficiency with 120 VDC Loads - 95% @ 6kW, 95.7% @ 3kW and 94.4% @ 1kW.
  - Input Impedance - Pass per SSP 57000, 3.2.2.7.1.
  - Stand Alone Stability - Pass per SSP 57000, 3.2.2.10.
  - Large Signal Stability - Requirement calls for recovery of the input voltage transient in 1.0 msec. Tests showed recovery time of 1.2 to 1.4 msec.
  - Common Mode Noise - Pass per SSP 57000, 3.2.1.4. Maximum Ripple Voltage Emissions - Pass per SSP 57000, 3.2.2.9.
  - EMI - Passed all tests per SSP 30237 except CS01, Conducted Susceptibility, 5Vrms input signal 30 Hz - 50 kHz. Peak input voltage exceeded the OV trip level of 126 VDC. Over-voltage level was raised to avoid problem. Confirmed by test run at 116 VDC with no instabilities or susceptibilities detected.
  - Thermal Vacuum Test - Pass per EPCU specification, thermal characterization and cooling profile tests completed in air and vacuum.
  - Vibration Tests - Pass per EPCU specification, tests performed at previous MPLM levels and revised MPLM levels.
- RFP will be issued for qual. unit. Qualification unit to be delivered during FY 2000.



EPCU Location in CIR Rack

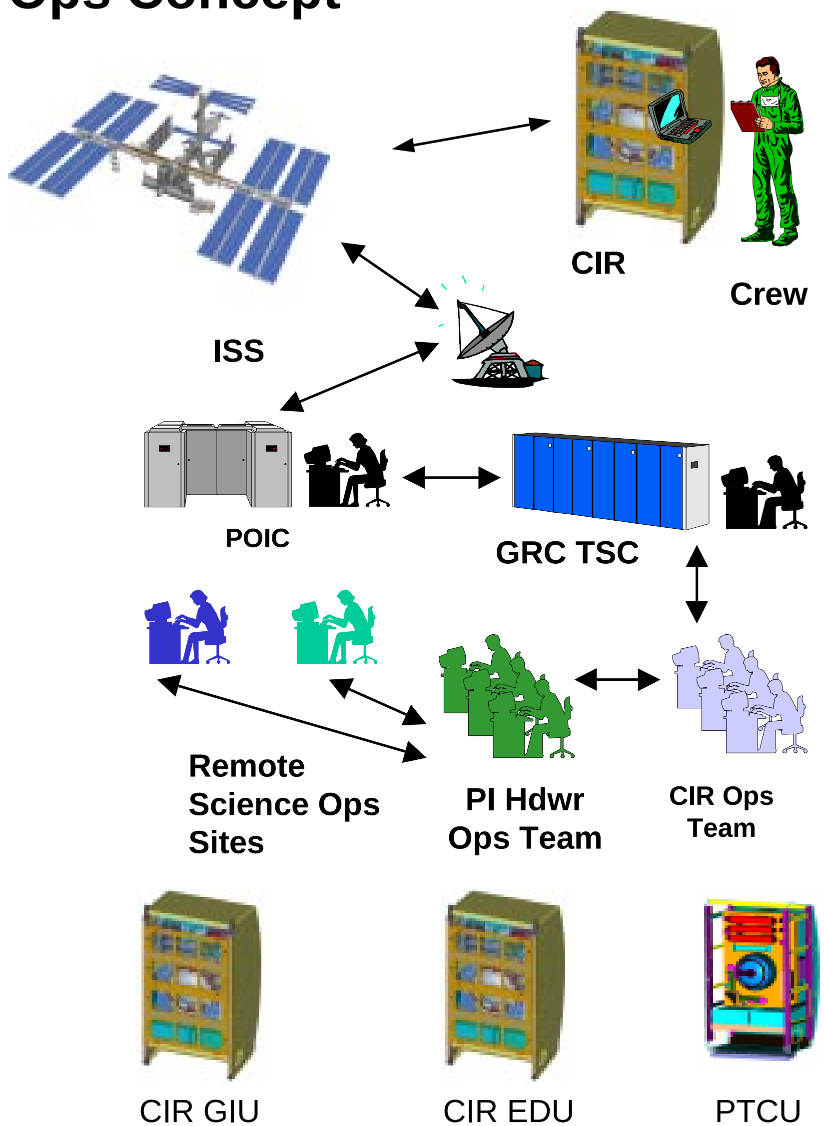
CIR Software

Joe Ponyik

Frank Novak

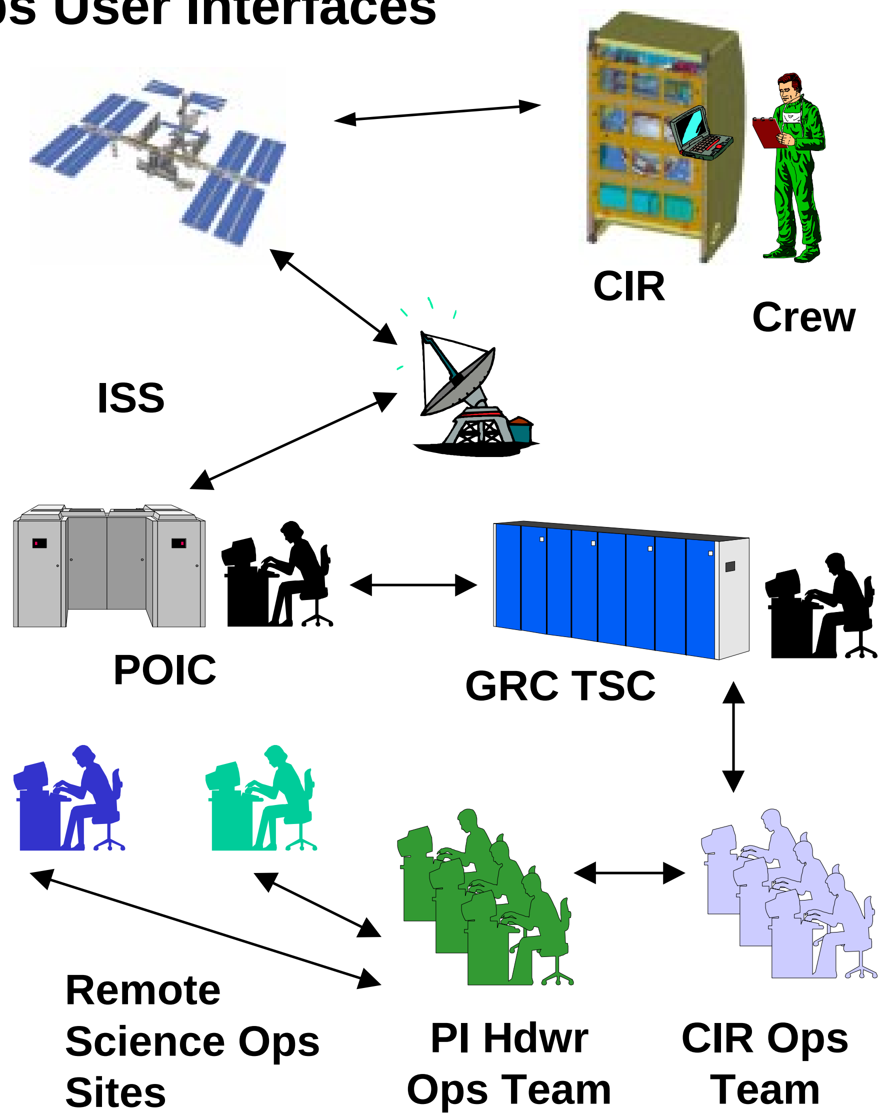
CIR Software Ops Concept

- **There are several users of the CIR System**
  - Crew
  - CIR Ops Team
  - PI Hwdr Ops Team
  - Remote PI's
  - POIC Cadre
  - Software developers working future increments
  - Ground Segment personnel
- **Several different systems require software**
  - Flight Segment
  - Real-time ops ground systems
  - Ground Integration Unit (GIU)
  - Engineering Development Unit (EDU)
  - PTC Training Unit (PTCU)



CIR Real-Time Ops User Interfaces

- **Crew**
  - Crew primary function is initial system and experiment set-up, and systems and experiment monitoring.
  - Will not require detailed subsystem displays.
  - C&W displays will be developed for the ISS systems laptops.
- **Ground Ops Teams**
  - Overall CIR and experiment planning, system and experiment monitoring, commanding and re-planning.
  - Within ISS comm system constraints, monitor real-time system status
  - Experiment operations will be defined in windows,requires commanding and a scripting language.



CIR Life Cycle & Ground System Software

- Flight Software is designed to accommodate new hardware and software configurations. (I.e. new PI Hardware and software)
- Goal is to minimize the amount of new software required for a new configuration.
- For each configuration, software will be required for the Flight Unit, the GIU, the EDU, the PTCU, the real-time ops ground system, and test scripts for the PRCU.
- All new flight software loads will need to be validated and verified before being uplinked.
- During PI Hardware integration testing several active software loads will be available at any one time.

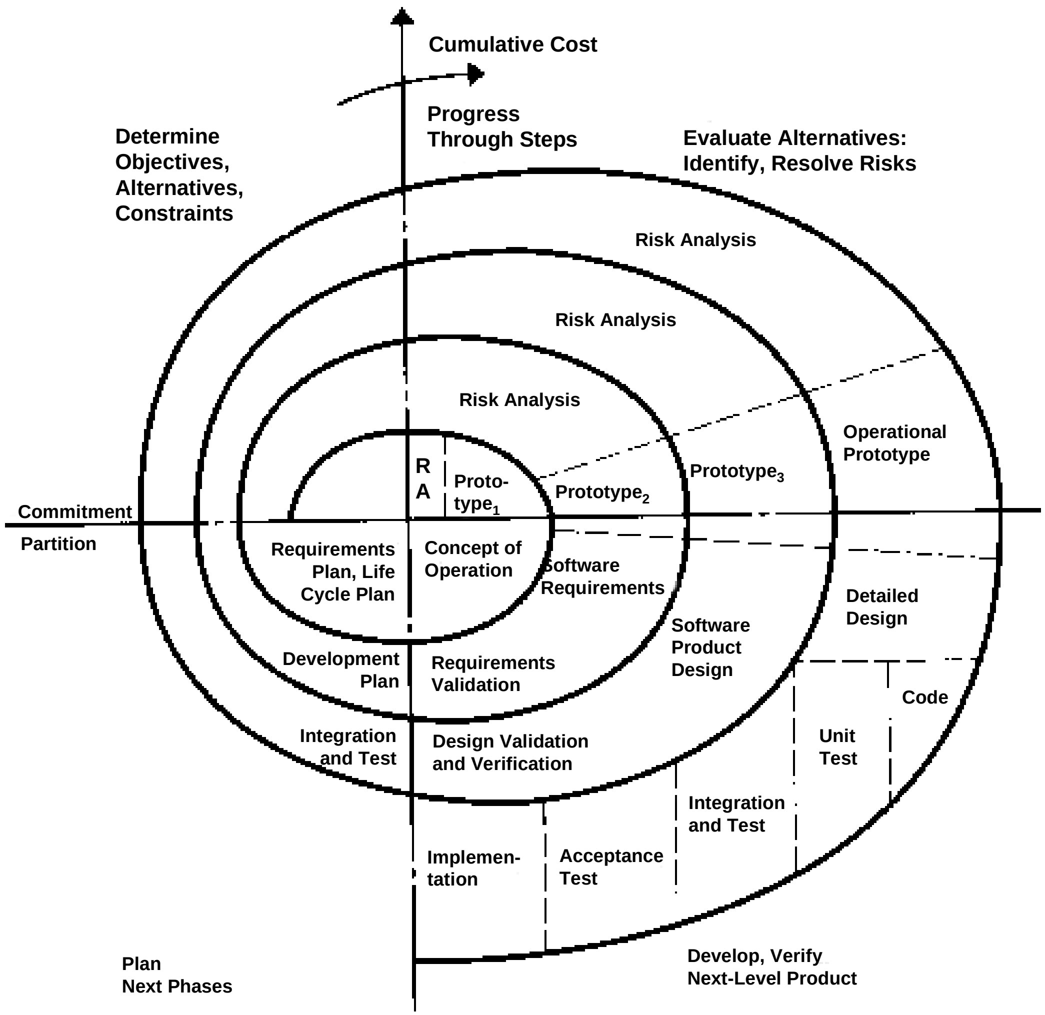
Ground Integration Unit & Payload Rack Checkout Unit

Payload Training Center Unit

Engineering Development Unit

SW Spiral Lifecycle

- A phased approach to developing FCF Flight Software
- More accurately reflects what is really done
- Requirements and design evolve as more is learned from prototyping
- Allows for alternatives to be explored during software development
- Allows for rapid prototyping
- In FCF, the software for each of the three racks will evolve as each rack develops
- Stress Test and Laptop/IOP/FCU End-to-end test are early tests that are demonstrating various concepts



- Diagram from “Managing the Software Process” by Watts S. Humphrey of the SEI at CMU

FCF SW Tools

Description	Tool	Status
Operating System	VxWorks	Selected
Languages (Embedded)	C++	Selected
Language (GUI)	Java 1.1	Selected
Inter-process Communications	CORBA (Orbix)*	Selected
Embedded Web Technology		Selected
C++ Compiler	GNU	Selected
VxWorks Dev. Env.	Tornado	Selected
Software Design Tool	Unified Modeling Language (UML)	Under Evaluation
Configuration Management Tool	CCC/Harvest, rcs	Selected

*Vendor in review

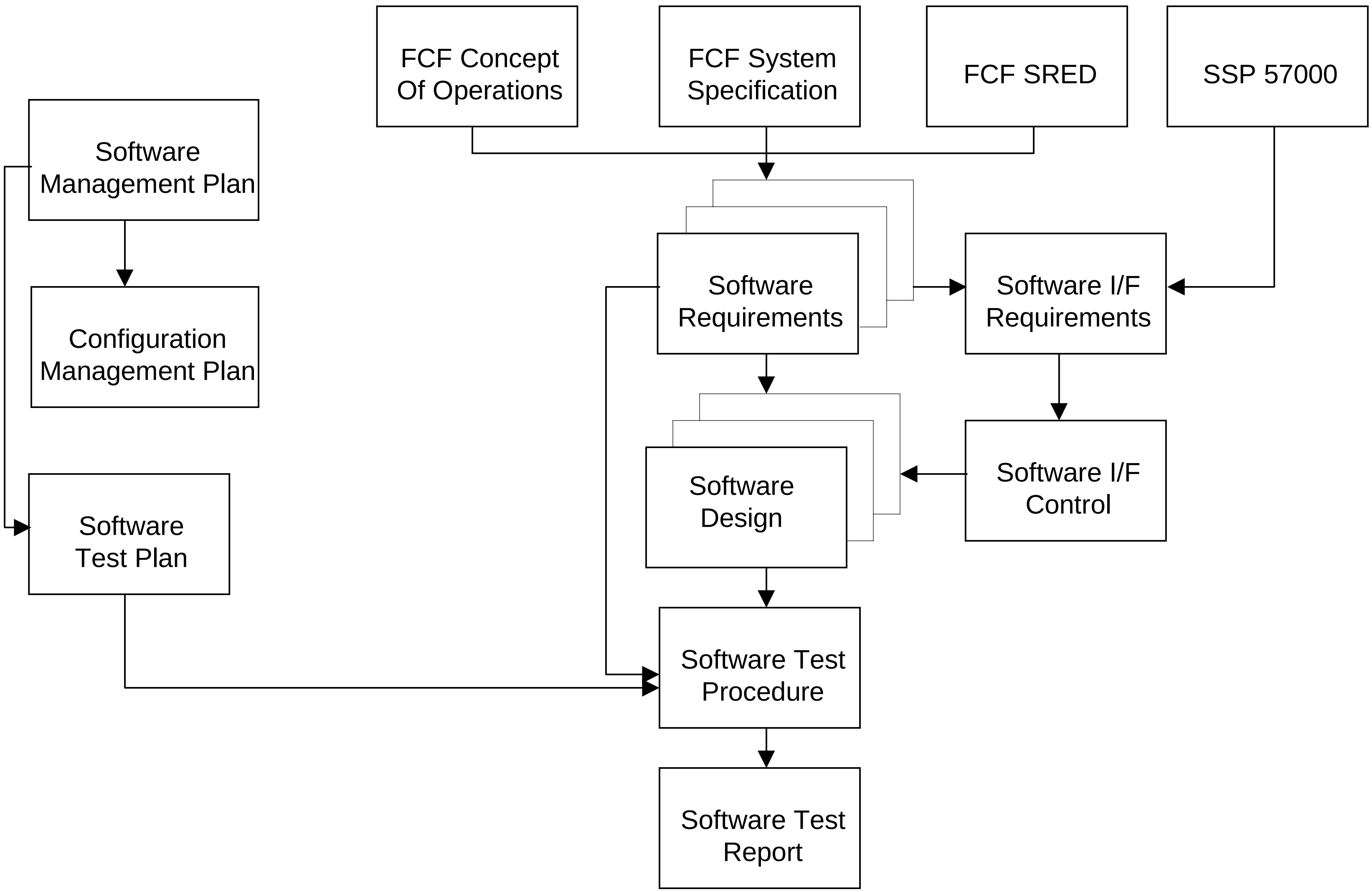
Embedded Web Technology

- What is it - The application of web based technologies to embedded software systems
  - CORBA (Common Object Request Broker Architecture)
  - World Wide Web standards - HTTP, HTML
  - Java
- Why use EWT
  - Only a browser required to run the user interface software
  - Cost savings through software reuse and portability
  - Allows FCF to take advantage of work done by thousands of others
  - Using commercial standards makes it easier to hire trained personnel
  - Simplifies the development and maintenance of FCF SW
  - No need to develop custom protocols
  - Allows for simpler upgrades and expansion in the future
  - Simplifies the incorporation of flight displays into ground operations
- Tempest, the web server in the IOP, won the 1998 NASA Software Of The Year Award

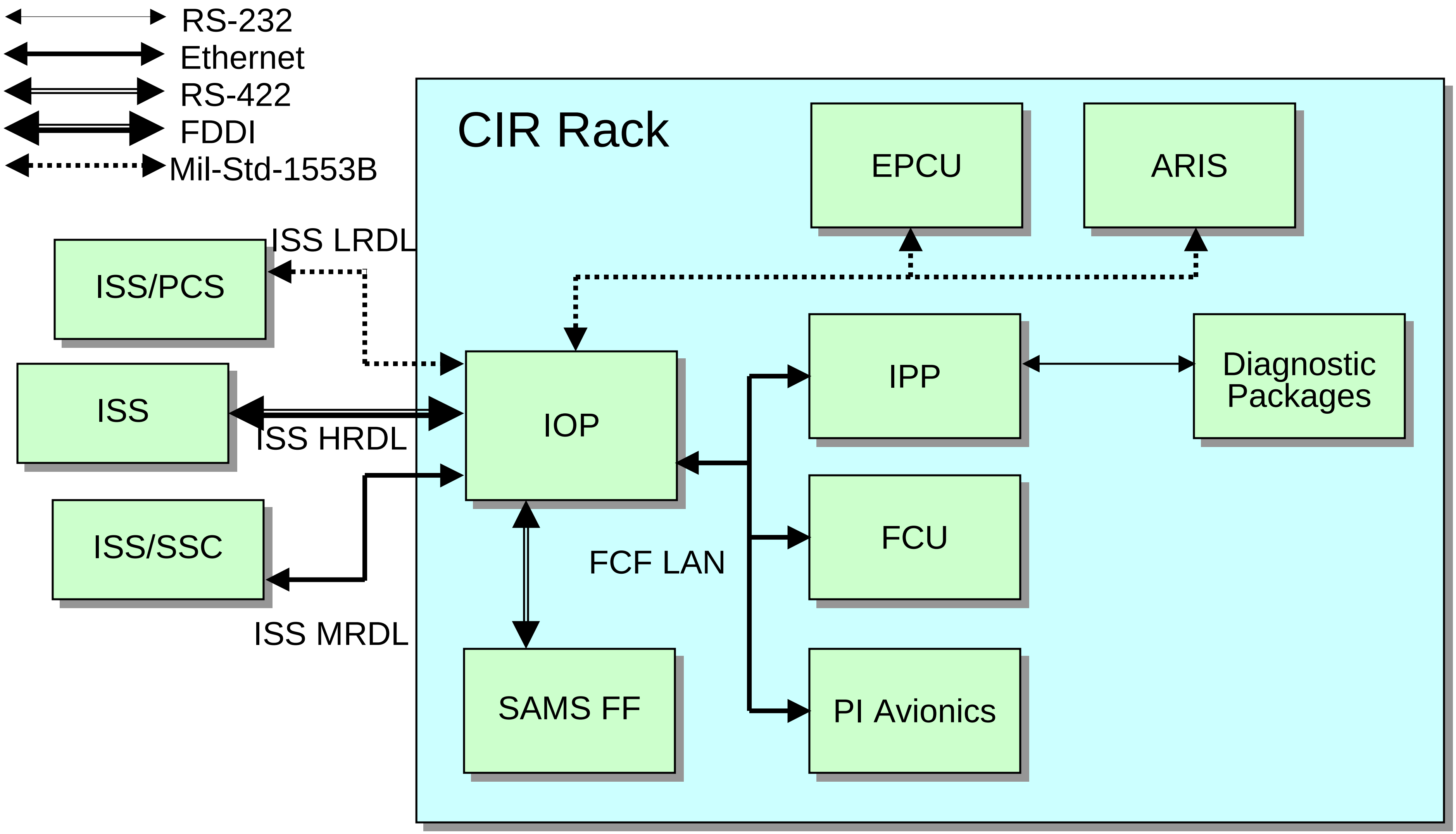
Embedded Web Technology

- How will it work onboard the ISS
  - Initially, crew will be required to connect the SSC to the FCF LAN
    - All other payloads and facilities work this way
    - ISS Payload LAN currently does not support TCP/IP
  - Bob Mortonson/Boeing working to determine what is needed to upgrade the Payload LAN to support TCP/IP
    - Architecture changes have been determined
    - CRs 1507 and 1508 to upgrade the Payload LAN in the works
  - When Payload LAN is upgraded, FCF will not need to change
    - Crew will be able to plug in to anywhere on Payload LAN to access FCF
    - S-POCCB, chaired by Neil Woodbury/JSC, pushing all payloads to implement a web-based interface

FCF Software Documentation Tree



CIR SW Interface Diagram



CIR SW Requirements

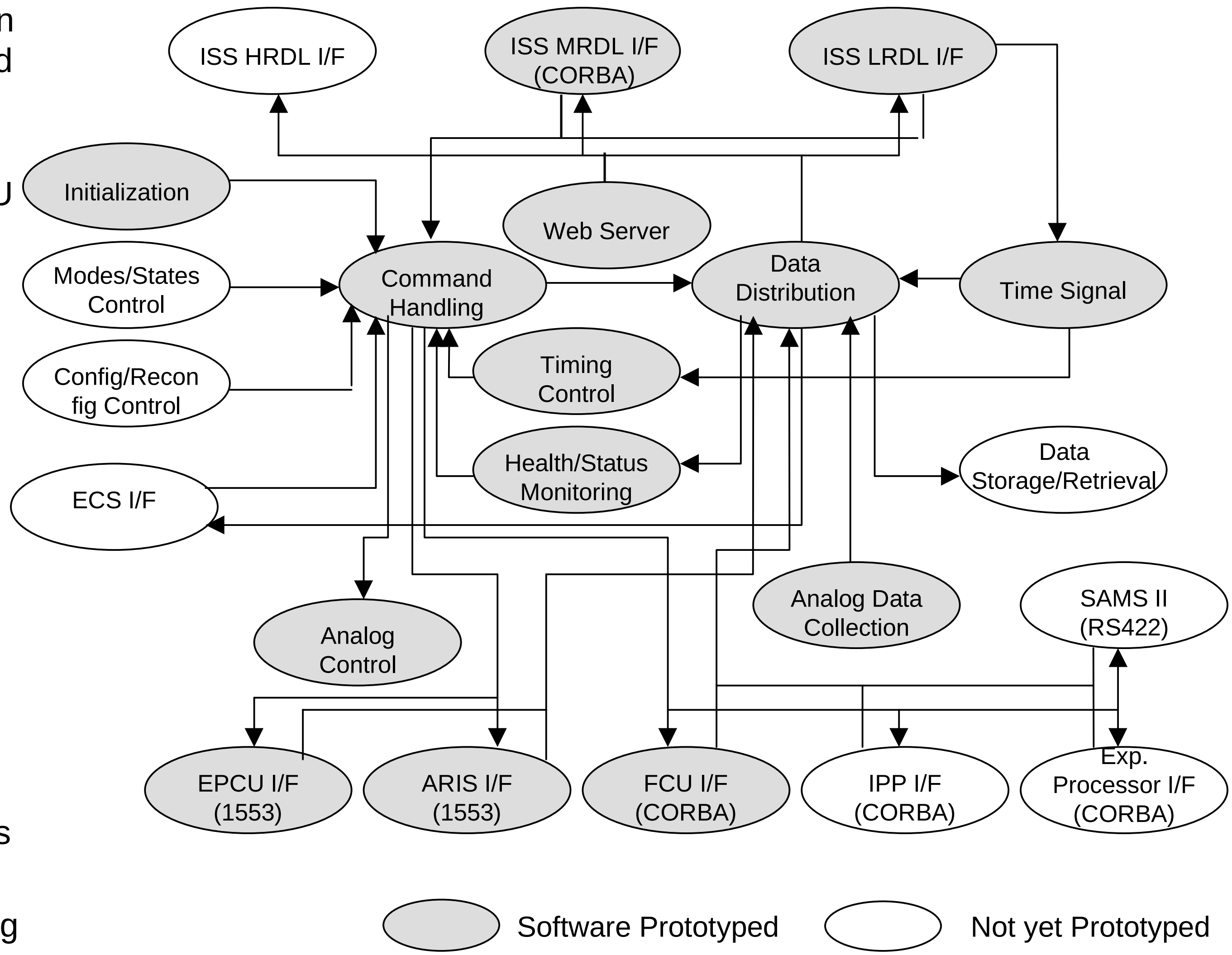
- **Requirements derived from - SRED, BCD, BSD, FCF System Spec**
- **IOP Requirements**
  - **Mode and state control, maintaining cognizance of current and expected status of CIR systems and PI hardware**
  - **Top level command and control**
  - **Data collection and distribution**
  - **Caution and Warning**
  - **Health and Status monitoring**
  - **Timing control - both time sync and experiment timelining function**
  - **Startup and shutdown of CIR systems and PI hardware**
  - **Hub gateway**
  - **ECS control**
  - **EPCU Control**
  - **ARIS Control**
  - **ISS Interfaces**
- **FCU Requirements**
  - **FOMA command processing**
  - **FOMA control**
  - **FOMA health and status monitoring**

CIR SW Requirements

- **IPSU Requirements**
  - **Image acquisition, processing and storage**
  - **Initiate image downlinking**
- **HFR/HR Requirements**
  - **Controls HFR/HR hardware components**
  - **Performs health and status monitoring**
- **HiBMS Requirements**
  - **Controls HiBMS hardware components**
  - **Performs health and status monitoring**
- **Illumination Package Requirements**
  - **Controls Illumination Package hardware components**
  - **Performs health and status monitoring**
- **Crew User Interface Requirements**
  - **Provide displays for crew members**
  - **Command initiation and monitoring**
  - **FCF and Experiment control**

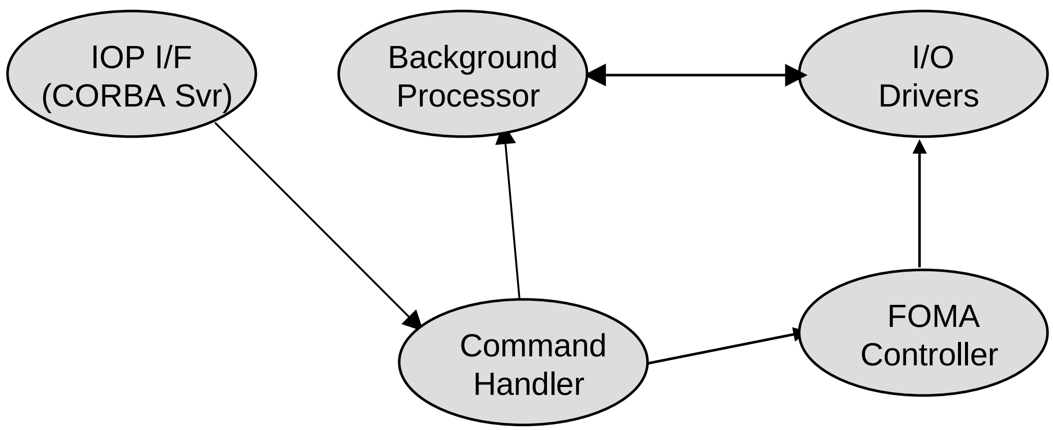
CIR IOP SW Architecture

- Shaded boxes indicate prototyping of functionality in Laptop/IOP/FCU End-to-end test or in Stress Test
- IOP establishes separate CORBA connections to FCU and Laptop
- IOP relays commands from Laptop to the FCU
- Mil-Std-1553B interfaces being developed using the STEP
  - ISS LRDL, EPCU and ARIS
- RS422 (SAMS) being developed
- Low level driver code functional
- Time sync protocol successfully tested in Stress Test
- Early results of stress testing show hardware is adequate



CIR FCU SW Architecture

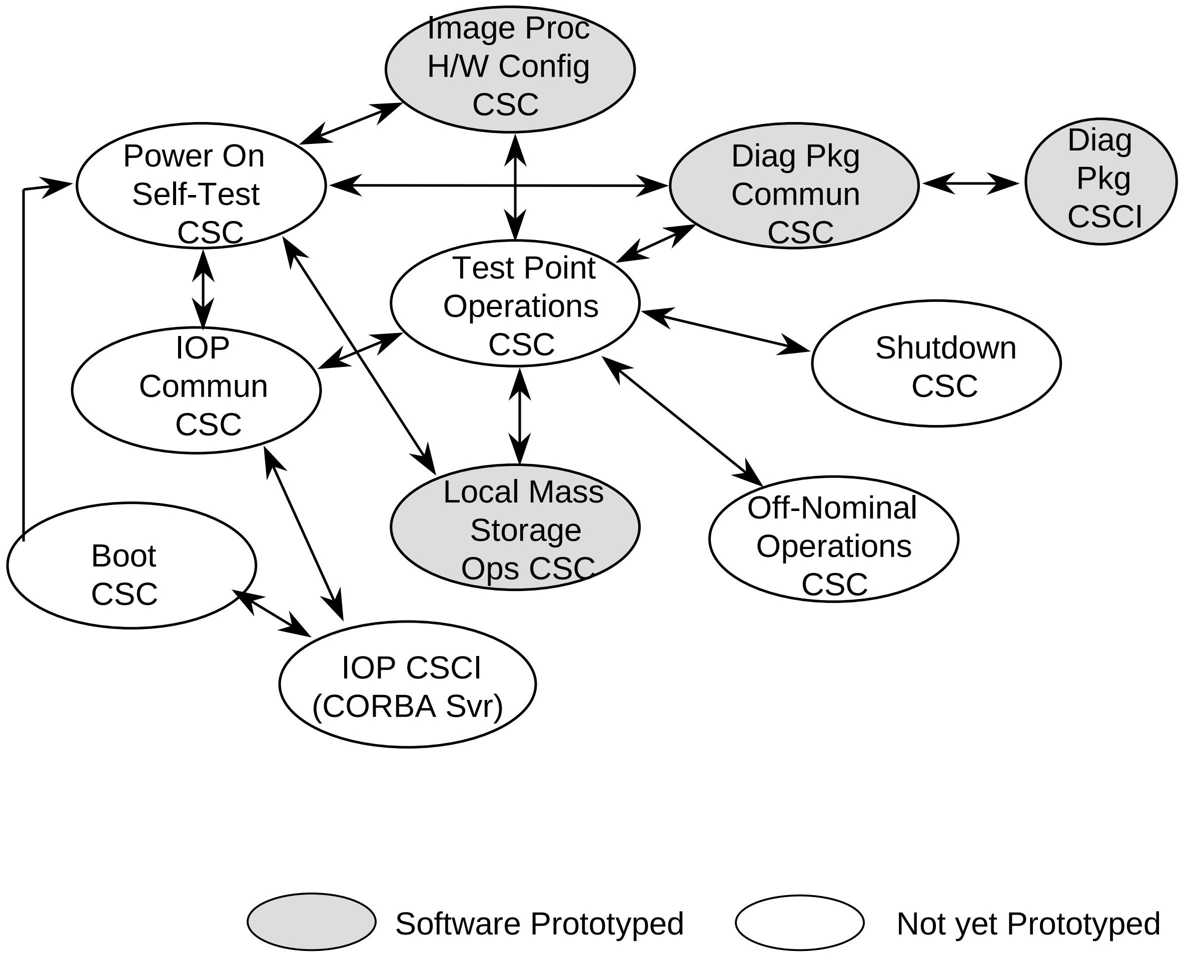
- FCU Development
  - Prototyping of functionality in Laptop/IOP/FCU End-to-end test
  - FCU establishes CORBA connection to IOP
    - Acts as a server for the IOP
    - Able to execute commands initiated from Laptop
    - Ability to blend gas demonstrated
  - Low level driver code is functional



Software Prototyped   Not yet Prototyped

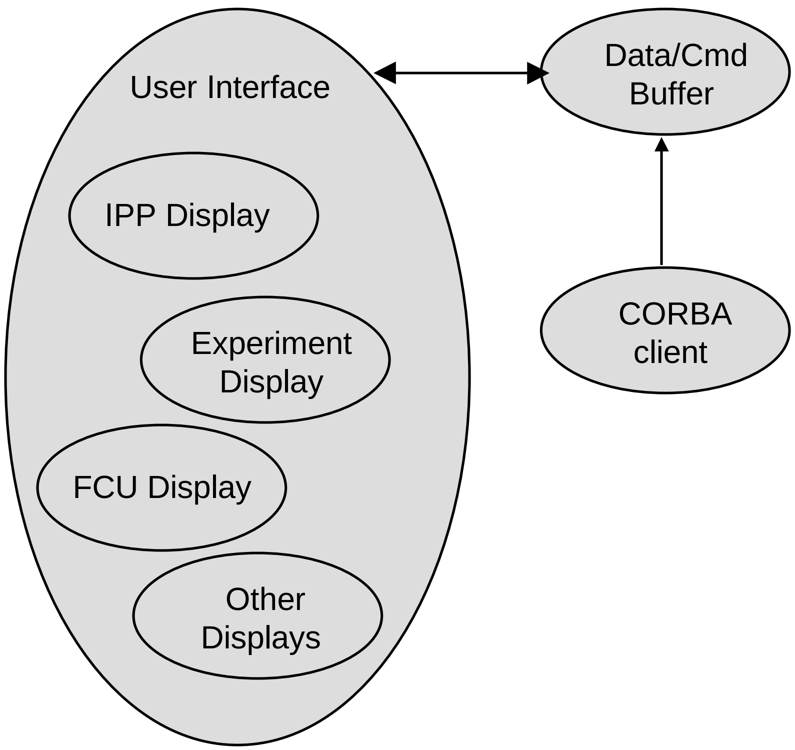
CIR IPSU SW Architecture

- Breadboard IPSU software has demonstrated critical IPSU functions:
  - Communications with imaging diagnostic packages
  - Camera configuration and control
  - Liquid crystal tunable filter configuration and control
  - Frame-by-frame control of camera integration time
  - Acquisition of images at frame rates up to 110 fps
  - Storage of images to magnetic media as TIFF files
  - Image cropping
  - Automatic object tracking
  - Automatic focus control
  - Generation of an event trigger (e.g. flame extinction)
  - Receipt of an event trigger to stop image acquisition
  - Live analog video output

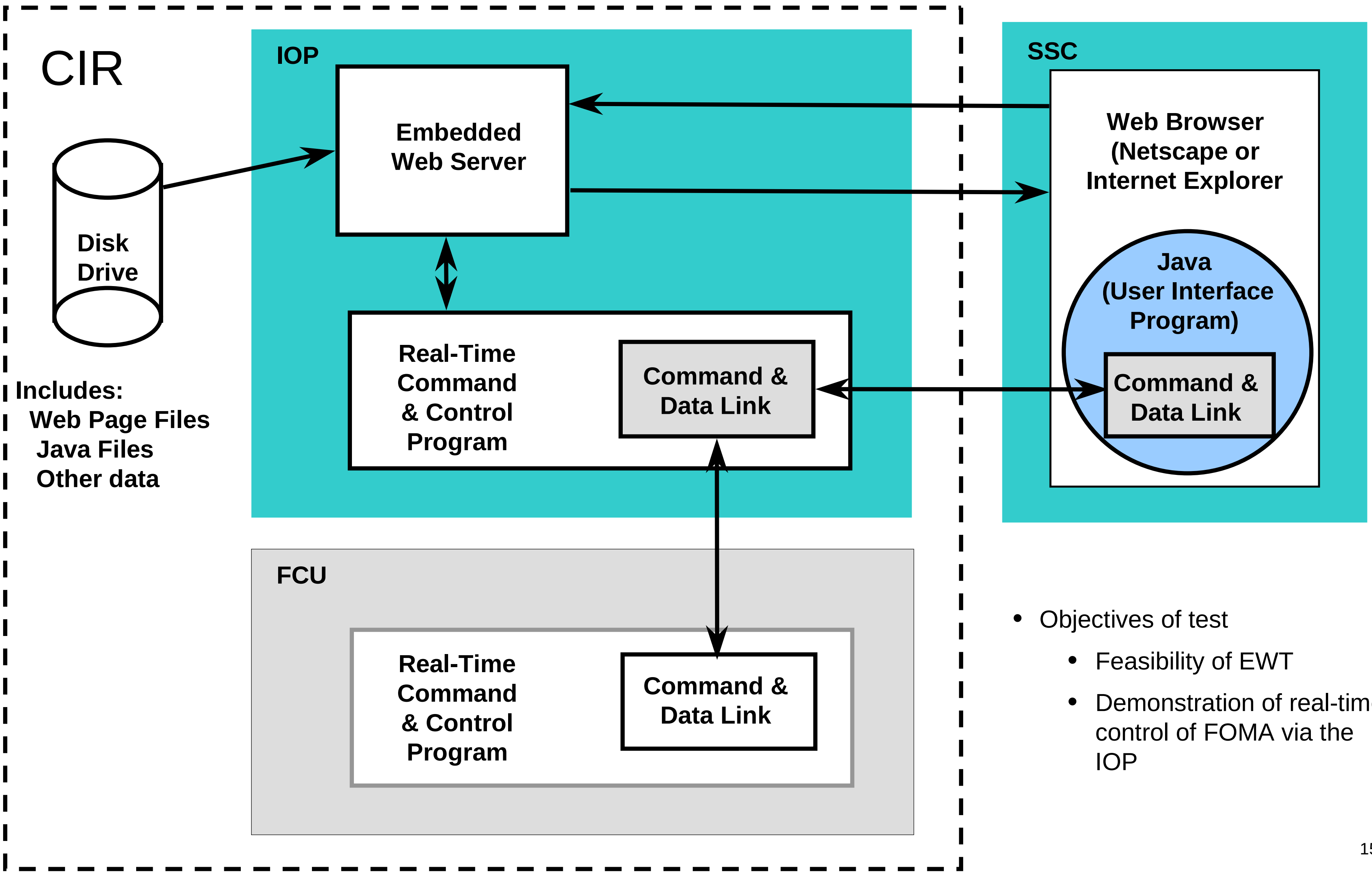


CIR SW Prototyping Status

- EWT and Laptop Development
  - Numerous demonstrations of EWT have been developed
    - HCR demo, Stress Test and Laptop/IOP/FCU End-to-end Test
  - Capability of IOP to act as a web server demonstrated
  - Java applets run on both Netscape and Internet Explorer
  - Regular participation in S-POCCB Telecon
  - Issues
    - User Interface Guidelines from ISS needed
      - Recently started participating in PSCP Telecon



Laptop/IOP/FCU End-to-end Test



- Objectives of test
  - Feasibility of EWT
  - Demonstration of real-time control of FOMA via the IOP

CIR Diagnostics

Nora Bozzolo

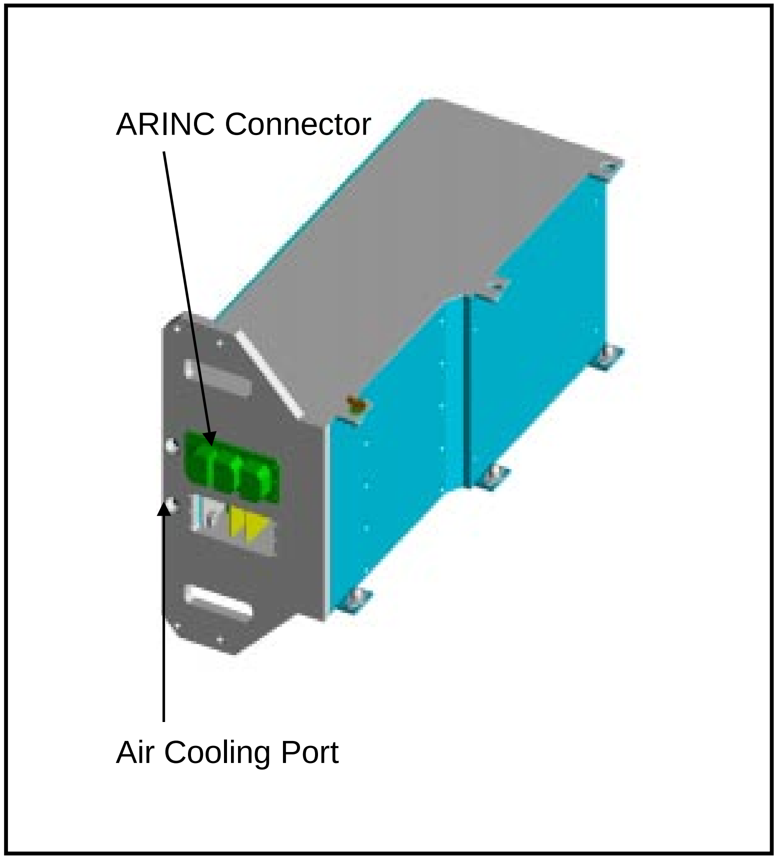
CIR Avionics - IPPs

Requirements

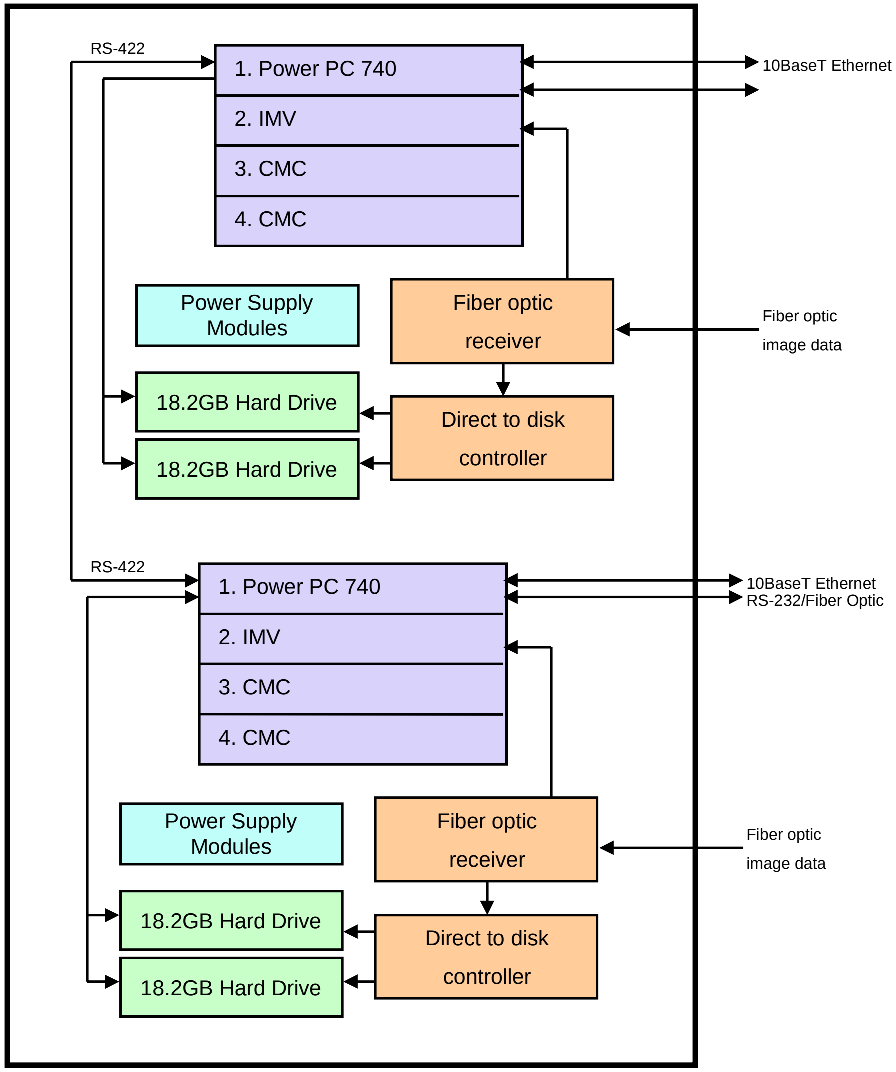
- Configure and control operation of CIR diagnostic packages
- Acquire and store images from CIR diagnostic packages
- Capture and record ancillary image data such as date & time
- Transfer images and ancillary data to IOP for downlinking
- Provide real-time analog video output

Description

- Each IPP consists of two independent Image Processing and Storage Units (IPSU's). Each IPSU can control one imaging diagnostic package and the Illumination package.



CIR Avionics - IPPs



Specifications/Features

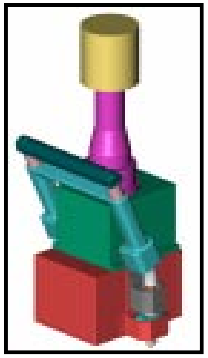
- Digital image acquisition at up to 40MB/s
- 36.4 Gbytes of image data storage direct to disk at 30MB/s. Sustained image recording > 20 minutes
- Real-time image processing for open or closed-loop control of diagnostic packages
- 256 Mbytes of image memory
- Fiber optic image receiver and interface to acquisition system
- RS-170 analog video output for real-time observation
- RS-422 IPSU to IPSU communication used for video event trigger control

Diagnostics - Overview

- Mounted on the Optics Bench using common interfaces to permit movement of packages to various window locations
- Diagnostics configuration requires Optics Bench fold down
- Design approach emphasizes electronic packaging modularity and maintainability.
- On-orbit change-out to support future grow
  - Entire package can be replaced at the Optics Bench interface
  - Designed for performance and technology upgrade
- Modular design for package reconfiguration
  - Optical components.
  - Five of the six imaging packages contain the same camera to minimize package control development and maximize camera change-out between packages
- Digital imaging technology implemented to collect and store data of the highest fidelity possible
- Imaging systems are supported by four dedicated Image Processing and Storage Units

HiBMs

HFR/HR



Color Camera

Low Light Level
UV & IR

Illumination

Near-IR

Diagnostics - Overview (cont'd)

- Blind electronic, power and avionics connections are provided to mate at the Optics Bench interface
- Avionics air cooling opening sized for each package cooling requirement
- Motor control and power conversion electronics are housed within the base of the package
- A removable latch mechanism is incorporated into the packages for attachment (and removal) to the Optics Bench
    - Latch provides repeatable package placement on the bench
    - 100µm alignment accuracy to the center of the chamber
- Packages contain embedded software for closed loop operations

Camera Bracket Side View

Camera Bracket Bottom View

Combustion Diagnostics Capabilities Summary

Package	Application	Pixels	FOV (mm)	Resol. (lp/mm)	Bit Depth (bits)	Run Time (min)	Frame Rate (fps)	Spectrum (nm)	Sensitivity	Features
HiBMs	Soot Volume Fraction Soot Temp. Shadowgraph	1024 or Bin 2x2	80 & 50 dia. Telecentric	5 & 10	12	20 @ 15fps	15	650 – 1050	N/A 1200K-2000K 0.8K/mm	Auto-iris
HFR/HR	High Frame Rate High Resolution	512 1024	10 sq. (37 total) Telecentric	12 @ 50% mod. 20 @ 50% mod.	8	20 @ 110fps or 30 fps	110 30	450 – 750	600 lux	Centroid Tracking Auto-focus Event Trigger
Color	Configuration Verification	512	58-350 sq. zoom	4.4 - 0.7	24	27 @ 30 fps	30	400 – 1050	2 lux	Auto-iris Auto-focus
Low Light Level	OH Emissions CH Emissions	1024	48-212 sq. zoom	12.1 - 2.4	8	20 @ 30 fps	30	280 – 700	6x10E-9 ft-candle	Auto-iris Auto-focus
Low Light Level	H_2O Emissions	1024	48-212 sq. zoom	12.1 - 2.4	8	20 @ 30 fps	30	500 – 875	4.4xE-9 ft-candle	Auto-iris Auto-focus
Mid-IR	Absorption Lines Temperature	320 x 244	183 x 138	0.9	12	20 @ 60 fps	60	1000 – 5000	-10C to 1500C	Auto-focus
Illumination	Calibration Bkgrnd Illum. Interferometry	N/A	80 dia. Collimated	N/A	N/A	N/A	N/A	3000K 675	5mW output	Light Source Selectable

Diagnostics - High Bit Depth/Multi-Spectral Imaging Package

Requirement

- Measure two characteristics of soot producing flames:
  - SVF: Volume Fraction (in conjunction with thermophoretic sampling)
  - ST: Temperature measurement (Two-Wavelength Pyrometry)

Description

- Spectrally filtered telecentric optical system and high resolution 12-bit output digital camera. Modular design to add Schlieren or shearing interferometer system

Specifications/Features

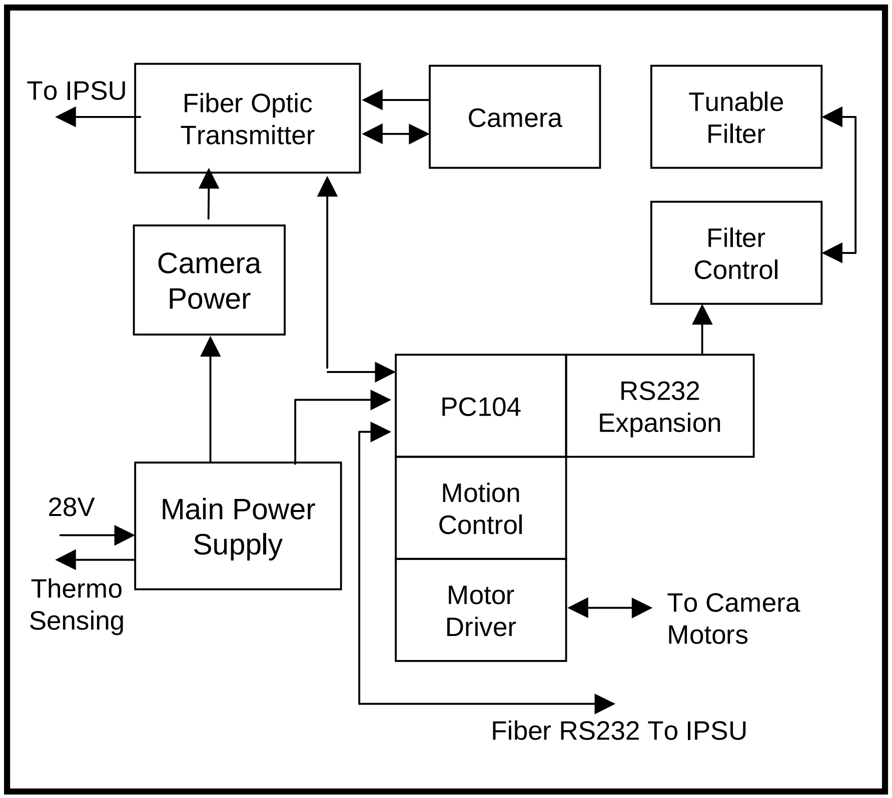
- Aperture adjustment programmable; Focus 208mm from inside surface of chamber window
- Liquid Crystal Tunable Filter (LCTF)
  - 10nm FWHM bandpass
  - 650-1050nm spectral range - 1nm spectral resolution - 100ms switching time between states
  - May be replaced with an RGB filter for field sequential color or removed for broad spectrum imaging
- Programmable frame rate (7.5, 15 or 30 fps) and exposure time
- Sub-frame storage options are available in the acquisition system to reduce data storage requirements

- SFV operates with Illumination package. Amount of laser radiation absorbed by soot is measured after selecting the LCTF at the laser wavelength
- ST measures flame emissions at any 2 (or more) wavelengths
- HiBMs with Illumination package may be used for shadowgraph measurement by setting the lens aperture to f/5.6 and LCTF at laser wavelength

HiBMs Package

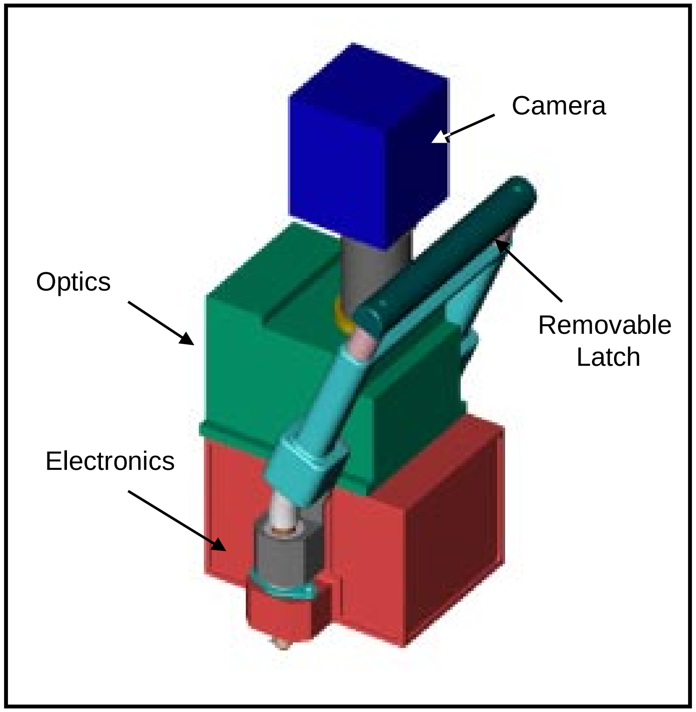
Diagnostics - High Bit Depth/Multi-Spectral Imaging Package

Electrical Schematics



Development Status

- Breadboard unit built and tested for optical performance, controls and embedded software development
- SVF, ST and shadowgraph operational modes were tested
- Engineering Model package design is in progress



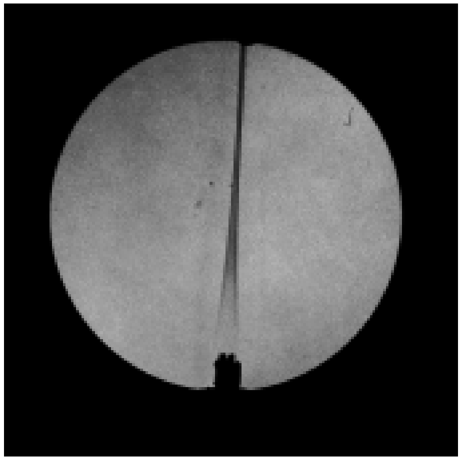
Diagnostics - High Bit Depth/Multi-Spectral Imaging Package

Tests Results

- Breadboard tests results are documented in CIR-RPT-0009

SVF Mode

- Images were taken at f/11, 30ms exposure and gain of 1
- LCTF tuned for 675nm center wavelength
- Ratios of background to absorption levels were measured based on data from line scans giving 1.27:1±0.09

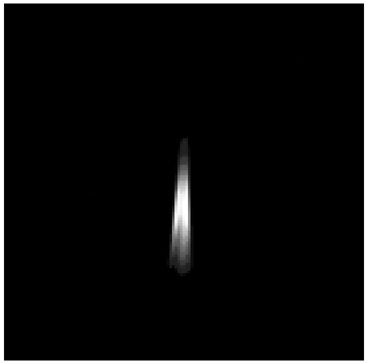


Gain 4; 60 fps

ST Mode (Two wavelength pyrometry)

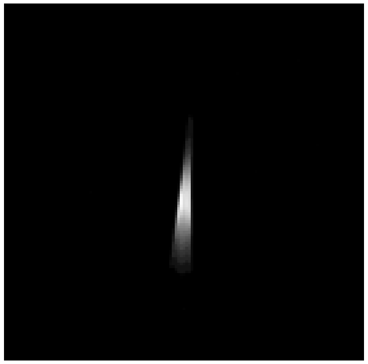
- Selected Wavelength: 650nm & 1050nm
- Filter least efficient at 650nm (10% transmission)
- Filter transmission is 30% at 850nm

Gain 4; 60 fps; f/4



650nm

Gain 4; 60 fps; f/16



850nm

Diagnostics - High Bit Depth/Multi-Spectral Imaging Package

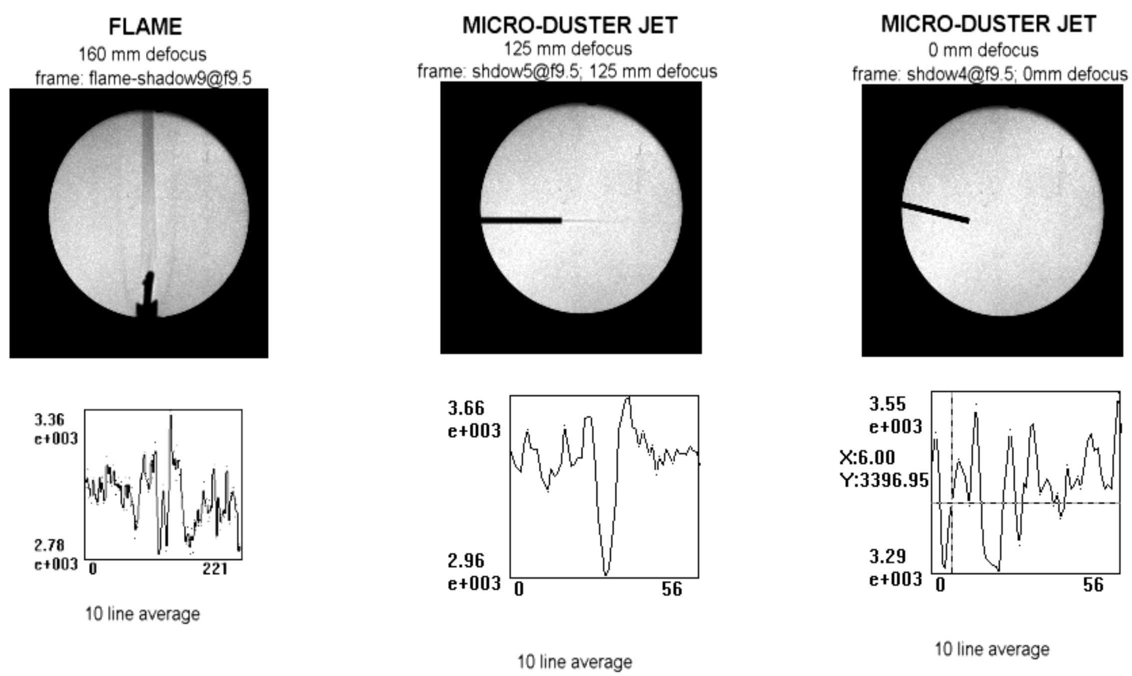
Shadowgraph Mode

- Shadowgraph sensitivity is maximized by matching the HiBMs aperture size to the size of the laser spot from the Illumination package. Best match is at f/9.5.
- Shadowgraph sensitivity is also increased by shifting the density gradient out of the HiBMs object focal plane.

EMI Testing

- Radiated and conducted emission tests have been performed conducted on the Silicon Mountain SMD-160 camera and power supply DC/DC converters per SSP 30237. No serious exceedances have been identified.

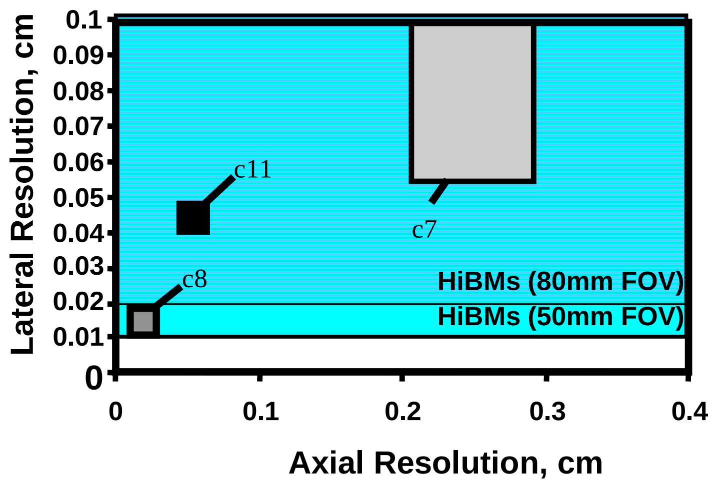
SHADOWGRAPH EFFECT

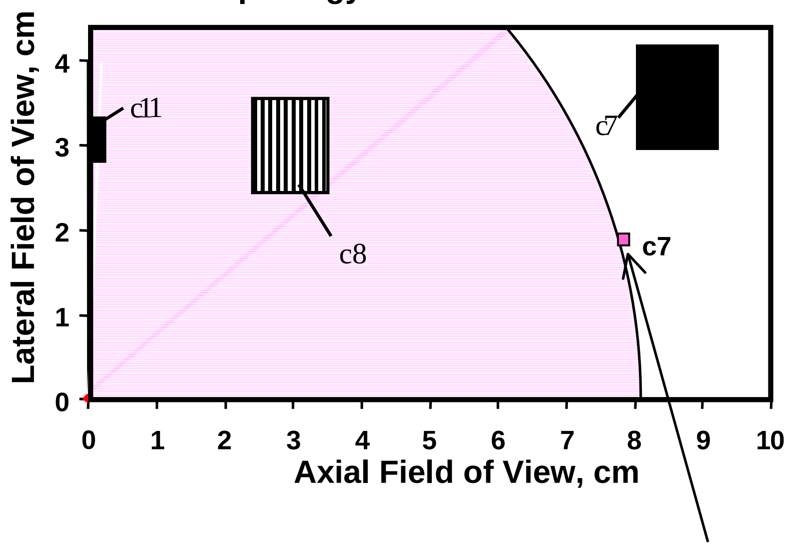


Diagnostics - High Bit Depth/Multi-Spectral Imaging Package

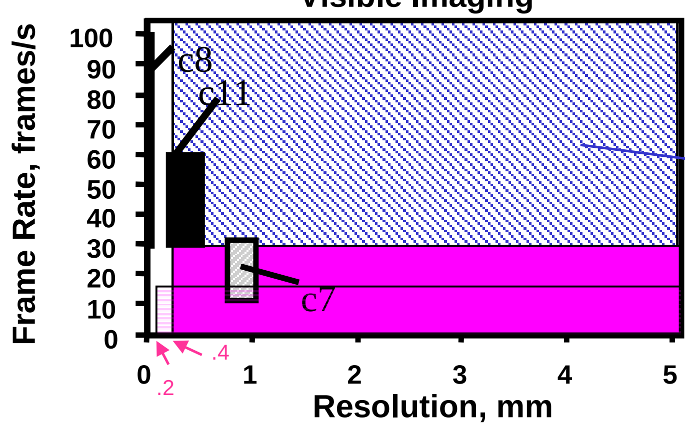
APPLICABLE SRED REQUIREMENTS

Soot-Volume Fraction, Temperature and Morphology





Visible Imaging



c3: SAL	c7: LSP
c8: SEDC	c11: TIGER-3D

Diagnostics - High Frame Rate/High Resolution Package

Requirement

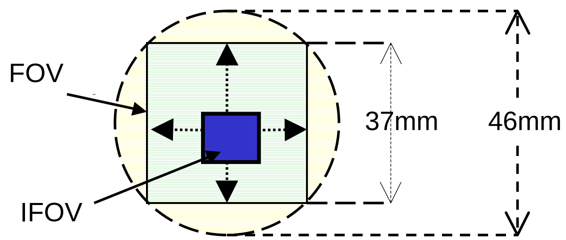
- Provide more than 30fps capability in addition to high optical resolution performance

Description

- Telecentric optical system, trombone prism assembly, LCTF and high resolution camera.

Specifications/Features

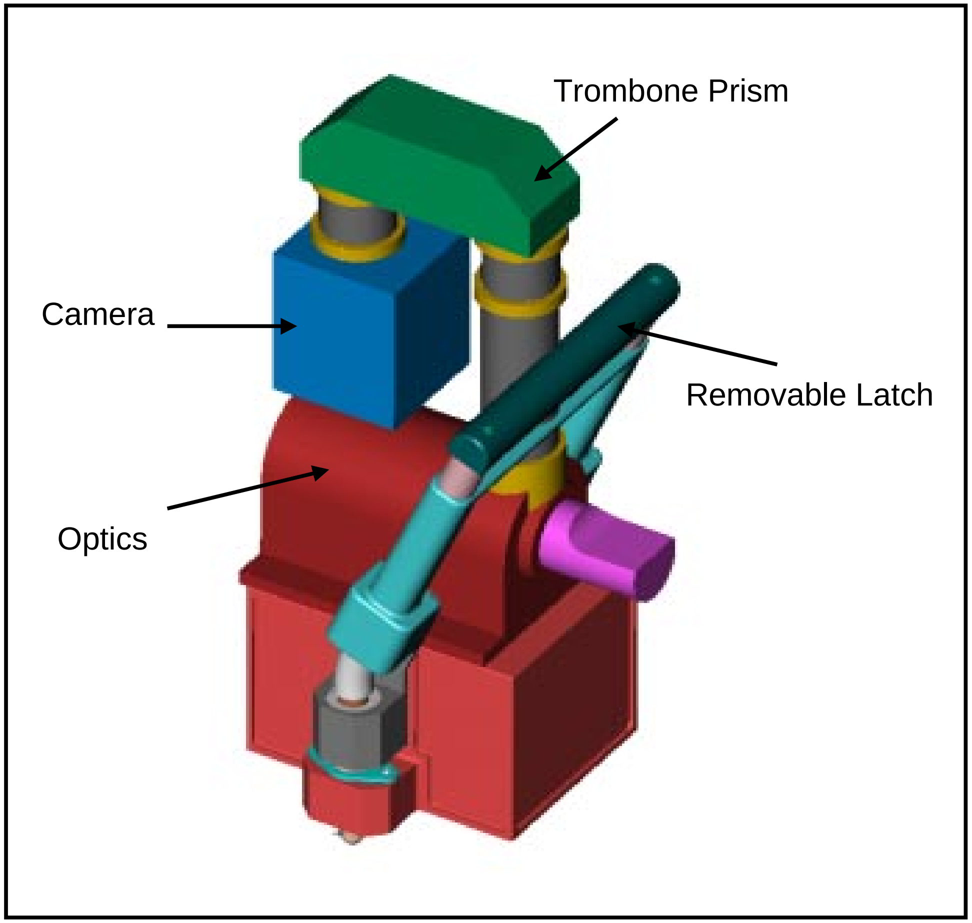
- Automated Tracking - Capable of steering a 9.3x9.3mm Instantaneous FOV (IFOV) over a total 46mm dia. total FOV truncated to 37mm horizontally & vertically



- 10mm/s maximum tracking speed
- Automated focus over 30mm object displacement - 5mm/s focusing speed
- Package accepts both bandpass and RGB liquid crystal filter expanding applications to ST and field sequential color imaging. The LCTF may be removed for broadband imaging
- Package may be programmed to sequentially operate in the 2 alternate modes
  - High Resolution Mode: 1024x1024 pixels at programmable frame rate of 7.5, 15, 15 or 30 fps
  - High Frame Rate Mode: 512x512 pixels at programmable frame rate of 60 or 110 fps
- Event trigger capability

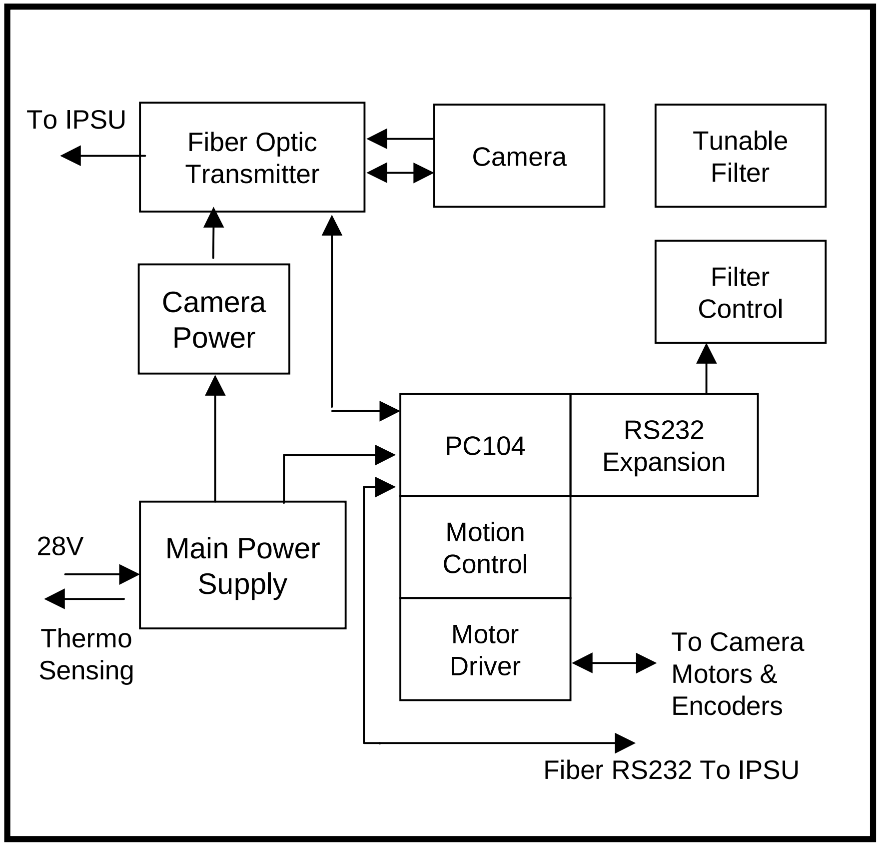
HFR/HR Package

Diagnostics - High Frame Rate/High Resolution Package



Diagnostics - High Frame Rate/High Resolution Package

Electrical Schematics



Development Status

- Breadboard unit built and tested for optical performance, controls and embedded software development
- Engineering Model design is in progress

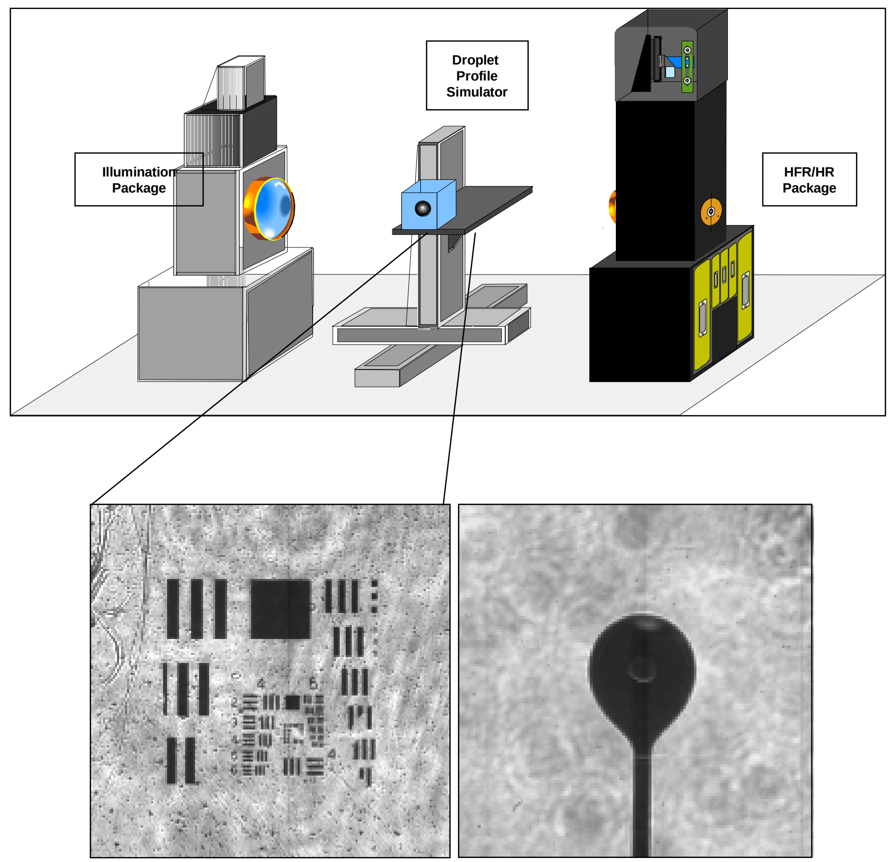
Breadboard Tests

- Initial breadboard tests results are documented in CIR-RPT-0009
- Tests were conducted to evaluate package capabilities:
    - Field of view (instantaneous& total)
    - Depth of field
    - Optical resolution for a moving target
    - Autofocus capability(total focus track length)
    - Tracking velocity

Diagnostics - High Frame Rate/High Resolution Package

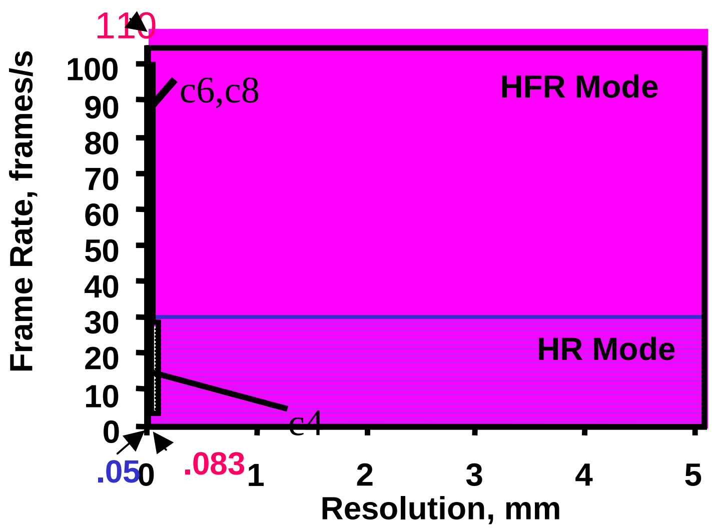
Preliminary Results

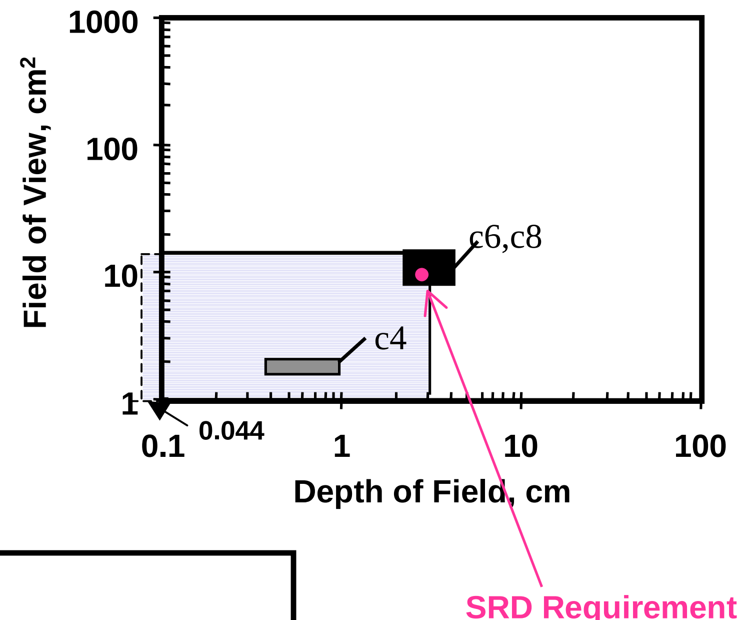
- Instantaneous Field of View 9.3 mm square
- Total Field of View (scanned) 37.1 mm square
- Total Depth of field 31.4 mm
- Tracking rate 0-10 mm/sec
- Focus rate 0-5 mm/sec
- Static resolution 25 lp/mm at 18% contrast



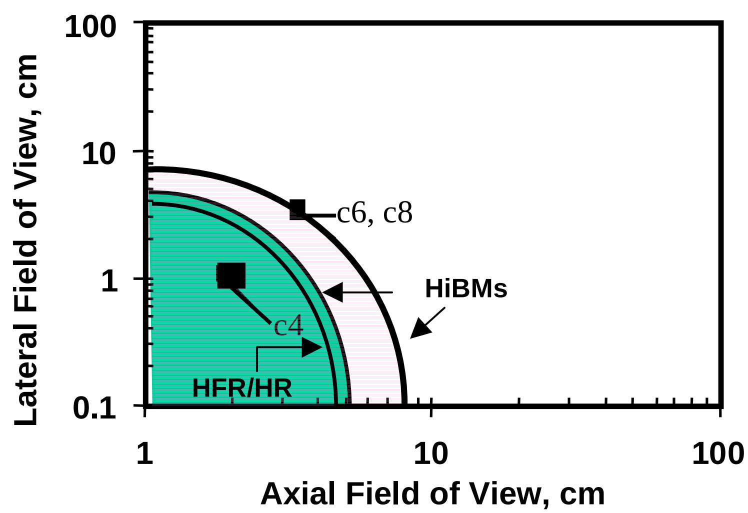
Diagnostics - High Frame Rate/High Resolution Package

Applicable SRED Requirements
Visible Imaging





c4: FIST	c6: DCE	c8: SEDC



Diagnostics - Color Camera Package

Requirement

- To provide color imaging of combustion, crew and ground checkout and verification of pre and post combustion event

Description

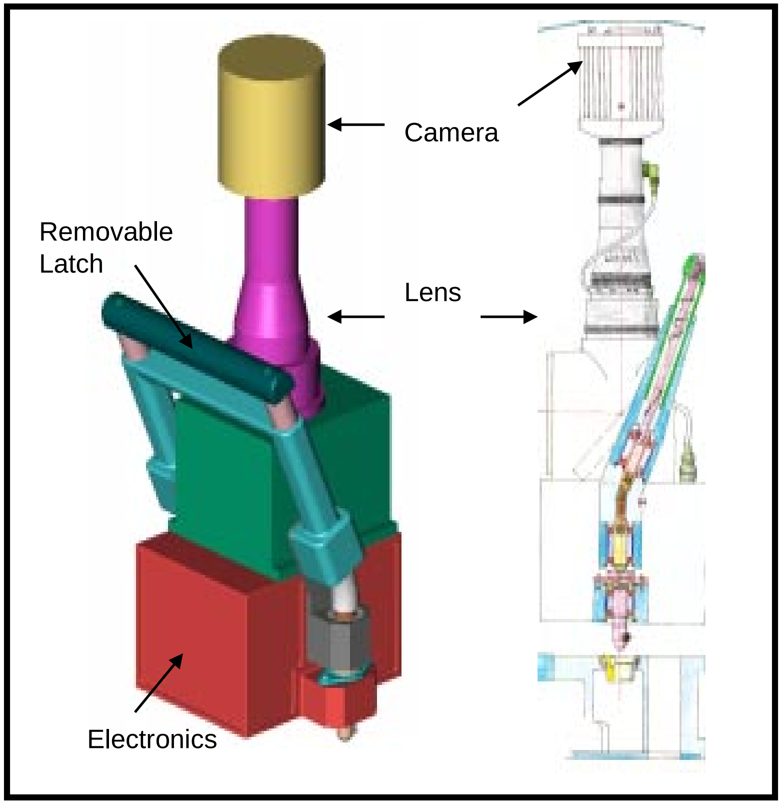
- Single chip frame transfer CCD with automated gain control, electronics shutter speed, external sync, white balance control and backlight correction. Color is obtained by field sequential operation of an RGB liquid crystal filter at up to 90 fields/sec.

Specifications/Features

- Modular package with 6X zoom lens and auto-iris. Lens can be removed for future upgrades
- Field sequential RGB output with 90 fields/sec or 30 fps capability - Lower framing rate capability with higher resolution performance at all colors (8.8 lp/mm)
- 2 lux Minimum illumination required with gain control capability. Gain may be programmed or set in the AUTO mode
- Automatic and manual white balance control
- Backlight correction
- Camera can operate with a minimum exposure time of 0.1ms

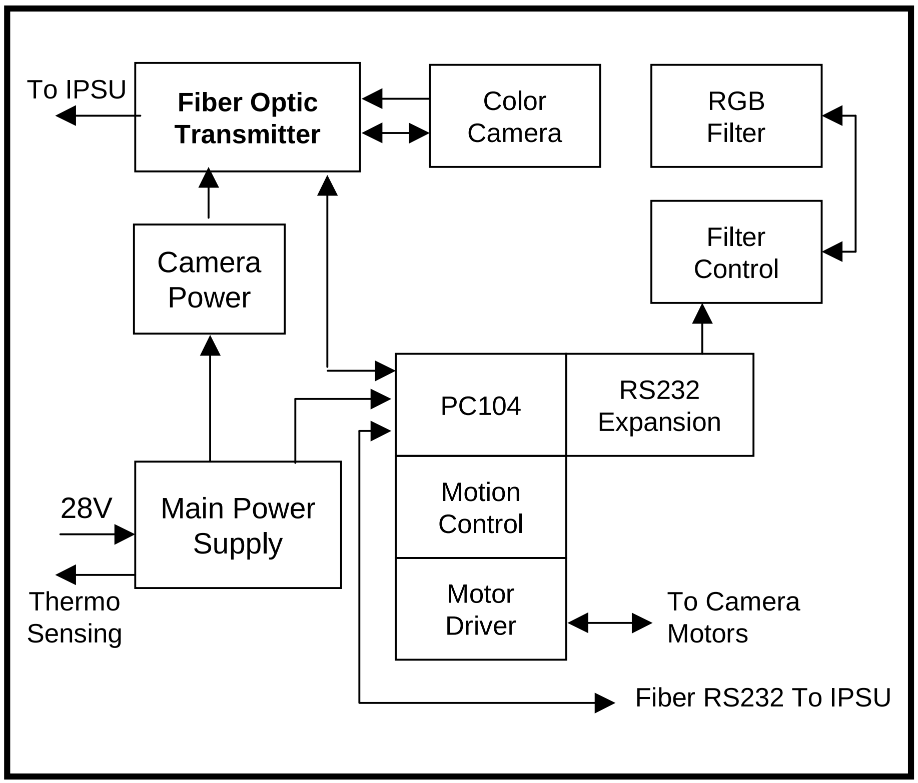
Development Status

- Currently working in the breadboard control and command development of the package.
- Mechanical Engineering Model design has been initiated.



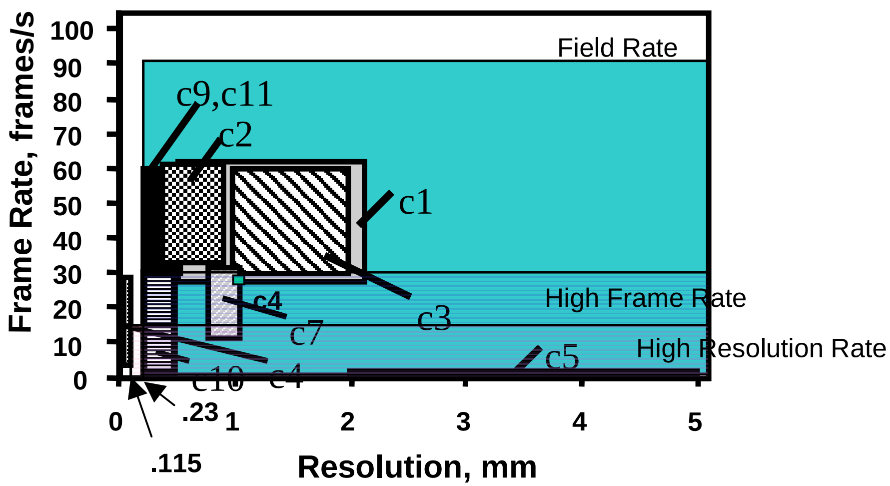
Diagnostics - Color Camera Package

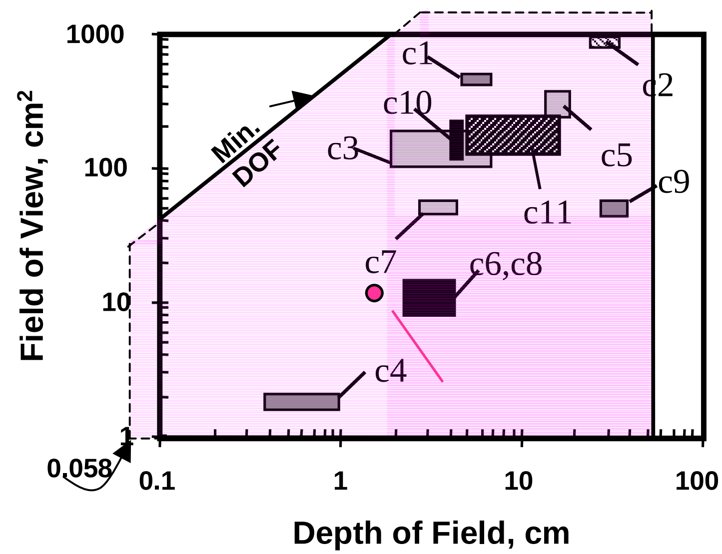
Electrical Schematics



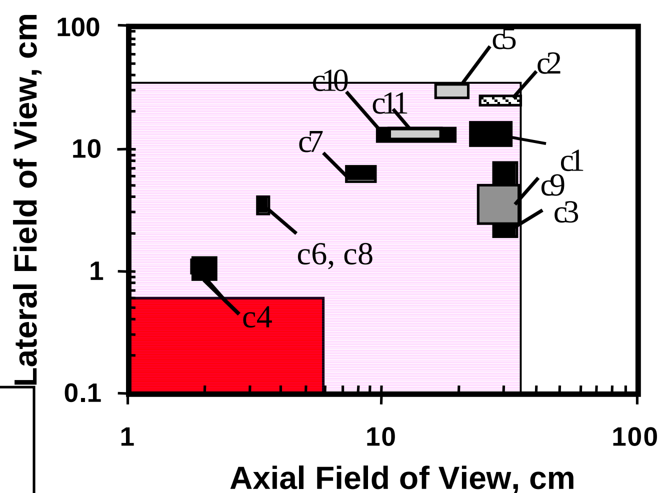
Diagnostics - Color Camera Package

Applicable SRED Requirements
Visible Imaging





All SRD requirements are within the SRED envelope



Zoom: 5.8cm to 35cm

c1: TGDF	c2: SOFBALL	c3: SAL
c4: FIST	c5: MSC	c6: DCE
c7: LSP	c8: SEDC	c9: SUBCORE
c10: SIBAL	c11: TIGER-3D	

Diagnostics - Low Light Level Camera Package

Requirement

- Provide images of events or objects at low radiance levels. Orthogonal views are preferred. Two spectral regions targeted.

Description

- Digital monochrome camera coupled to an intensifier with fast numerical aperture optics and provision for spectral filtering of the transmitted illumination.

Specifications/Features

- Two units being developed to provide imaging capabilities in two spectral regions
  - 280-700nm (UV shifted)
  - 500-875nm (IR shifted)
- Both units accept LCTF or standard bandpass. Filters are removable to offer broadband imaging capability
- For low frame rate requirements, and RGB filter can be installed to acquire color images is required

LLL Package

Diagnostics - Low Light Level Camera Package

UV

- Filtering at 310nm with a 10nm FWHM bandwidth is provided for OH imaging
- Unit equipped with a Gen II Intensifier with 6x10 $^{-9}$ft-candle minimum illumination required

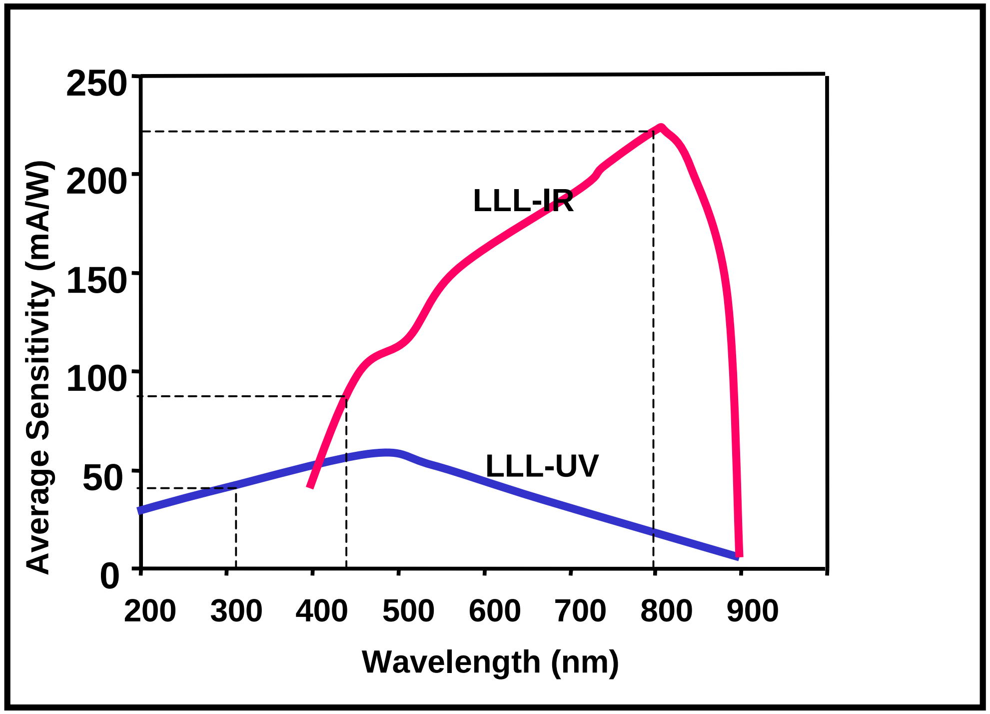
IR

- Filtering via LCTF is provided for H_2O imaging
- Unit equipped with Gen III Ultra intensifier with 4.4x10 $^{-9}$ft-candle minimum illumination required 60 fps is provided (resolution penalty)

- Intensifier gain control is programmable
- Adjustable and programmable aperture

Development Status

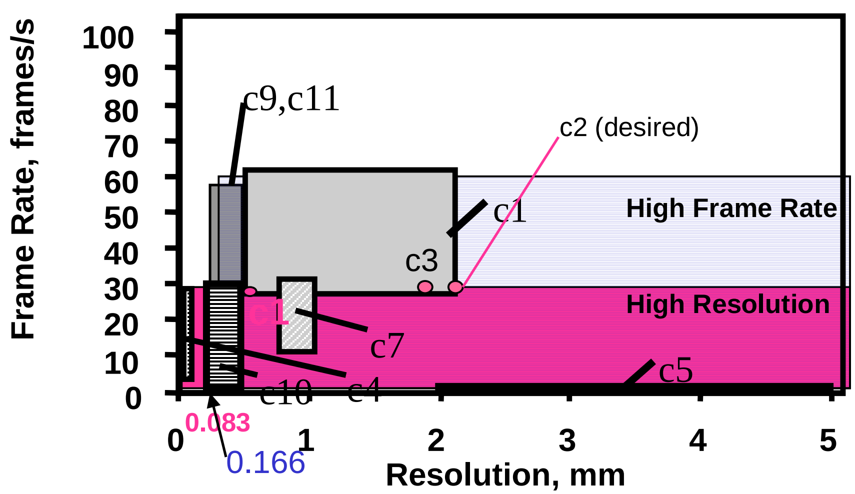
- Breadboard unit has not been built however basic electonics and controls are similar to HiBMs and HRF/HR packages
- Engineering Model design has not been initiated however standard package mount is planned

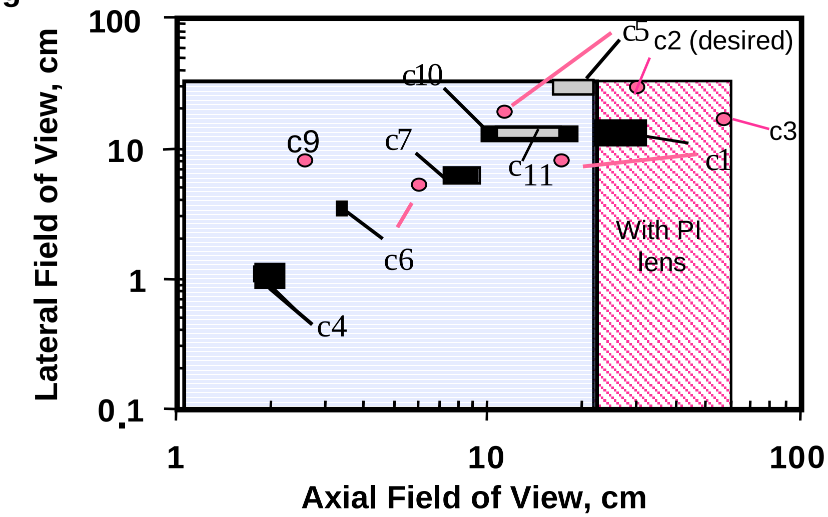


Diagnostics - Low Light Level Camera Package

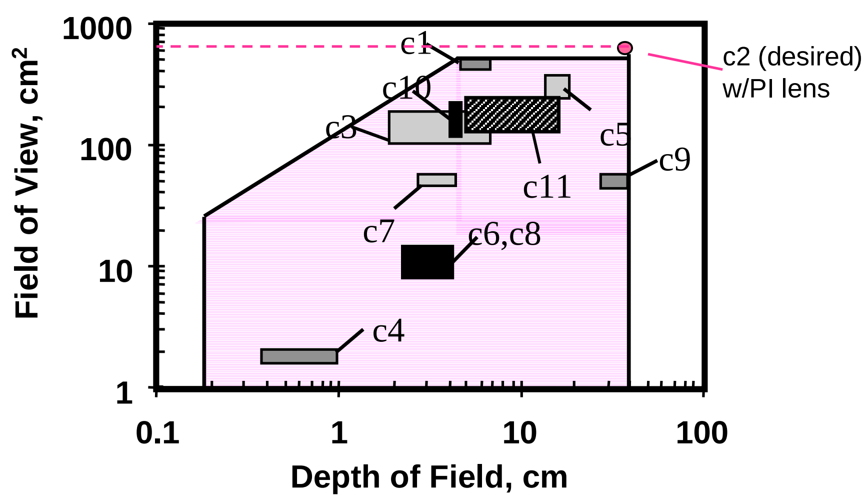
Applicable SRED Requirements

Visible Imaging





c1: TGDF	c2: SOFBALL	c3: SAL
c4: FIST	c5: MSC	c6: DCE
c7: LSP	c8: SEDC	c9: SUBCORE
c10: SIBAL	c11: TIGER-3D	

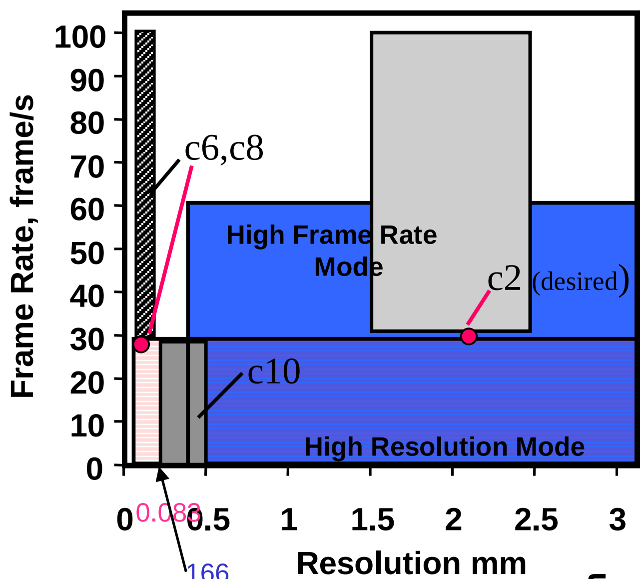


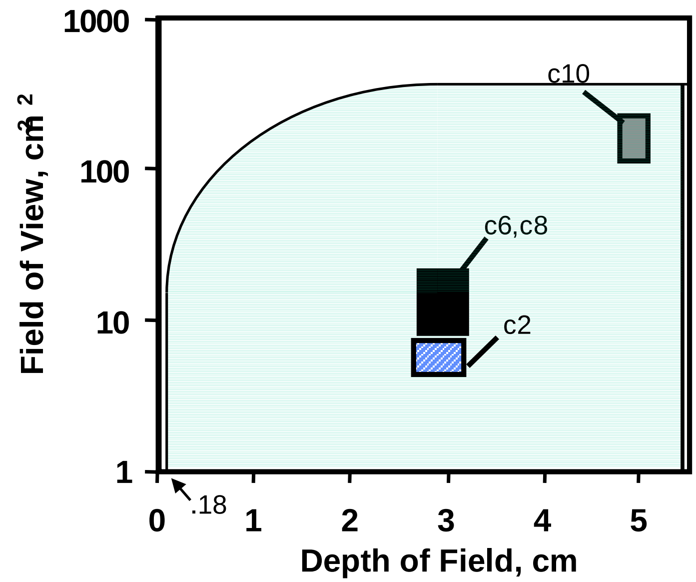
SRD Requirement

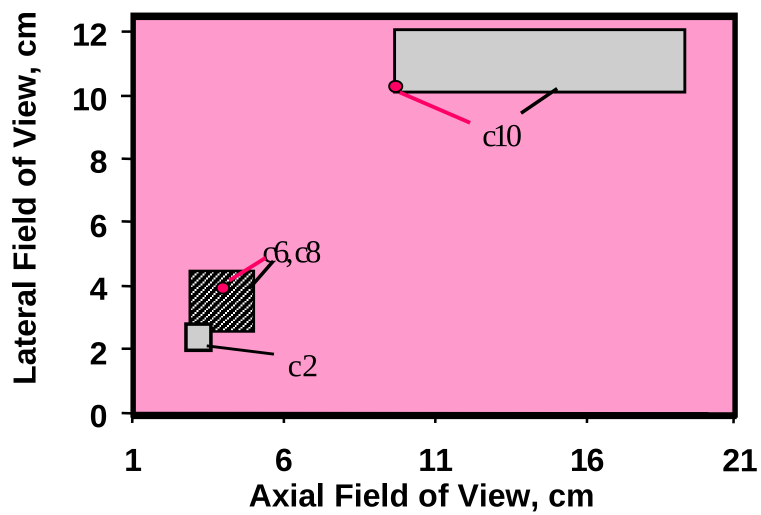
Diagnostics - Low Light Level Camera Package

Applicable SRED Requirements

Ultraviolet Imaging







c2: SOFBALL c6: DCE c8: SEDC
c10: SIBAL

SRD Requirement

Diagnostics - Mid-IR Camera Package

Requirement

- Provide images of events or objects emitting in the range of 1000-5000nm. Provide field temperature measurements.

Description

- Commercial optics and Stirling cycle cooled Focal Plane Array detector.

Specifications/Features

- Package accepts filters - Wavelengths of interest can be manually selected prior to package configuration on Optics Bench
- Temperature Range: -10C to 450C (up to 1500C if filter is used)
- Minimum Resolvable Temperature Difference: 0.2C @ 0.5lp/mm
- Automatic focus
- Automatic and PI defined calibration options (2, 3 or 4 point correction)
- Camera can be programmed to acquire images at PI selectable gain settings. This allows the PI to override the autogain to permit recording of faint emission or absorption lines in the presence of of brighter objects or to keep a bright small object out of saturation

Development Status

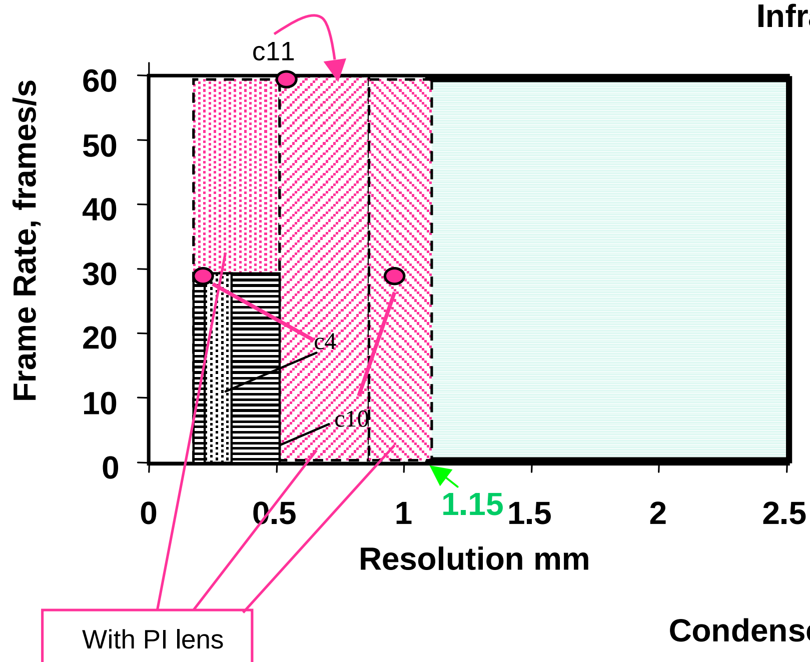
- No breadboard unit has been developed yet.
- Commercial unit currently being tested by some of the PI development teams

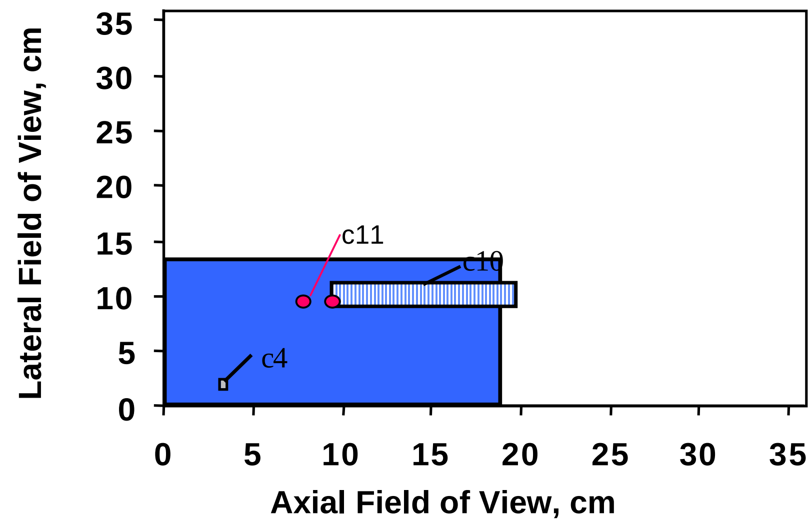
Mid-IR Camera

Diagnostics - Mid-IR Camera Package

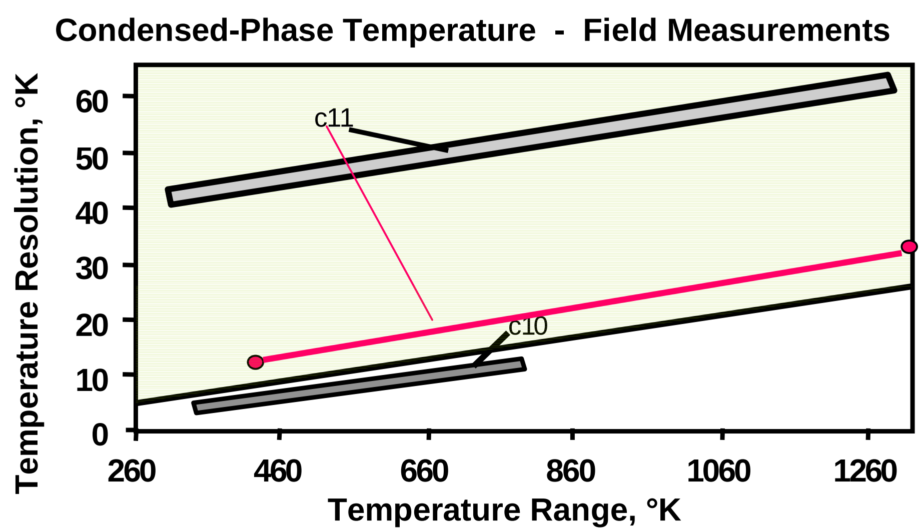
Applicable SRED Requirements

Infrared Imaging





c4: FIST   c10: SIBAL   c11: TIGER-3D



Diagnostics - Illumination Package

Requirement

- To provide illumination source to the chamber and support imaging packages where backlight illumination is required.

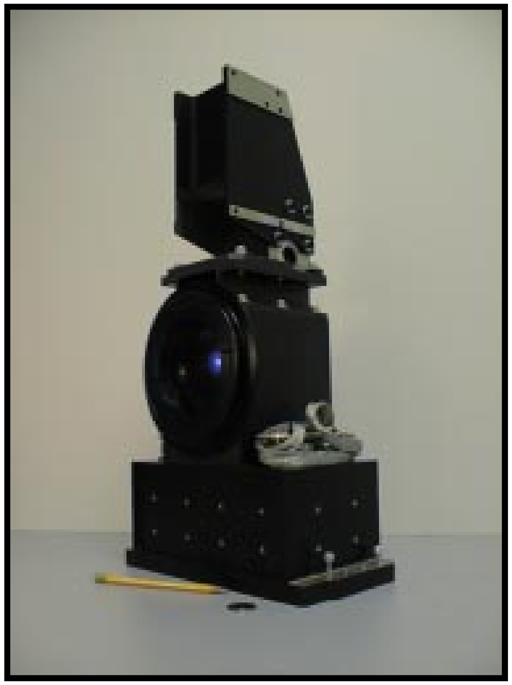
Description

- Collimated optical system with software controlled selector mirror and three illumination sources. One illumination source is a current stabilized Tungsten Halogen lamp that can be used for radiometric calibration. The other two sources are laser diodes, one with holographic diffuser and apodizer for uniform and coherence interference free illumination.

Specifications/Features

- Tungsten Halogen Source
  - 0.6 lumens/mm^2 with 70% illumination field uniformity
  - 7.6 milliradians divergence (programmable)
  - 3000K color temperature - 2% stability
- Diffuse Laser Diode Sources
  - 10mW Coupled Power. May be programmable
  - 78% Illumination field uniformity
  - 675nm wavelength & 7nm bandwidth
- Coherent Laser Diode Source
  - 5mW Coupled Power - Gaussian Illumination
  - 675nm Wavelength & 2nm bandwidth

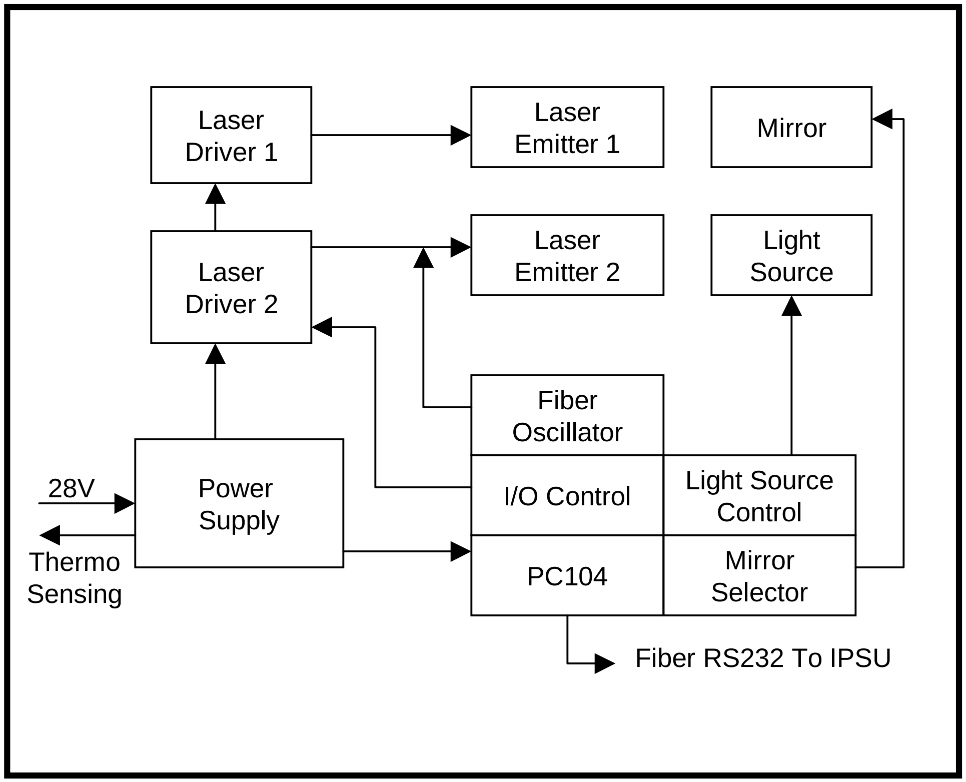
- Package can provide a uniform background illumination for light absorption measurements in SVF applications.
- The diffuse laser diode source can also provide illumination for shadowgraph measurements with the HiBMs and the HFR/HR packages.
- Any of the illumination sources can be synchronized with the imaging systems
- Modular design support future growth



Illumination Package

Diagnostics - Illumination Package

Electrical Schematics



Development Status

- Breadboard unit built and tested for optical performance, controls and embedded software development
- Engineering Model design is in progress
- All package testing has been done in conjunction with the HiBMs & HFR/HR package

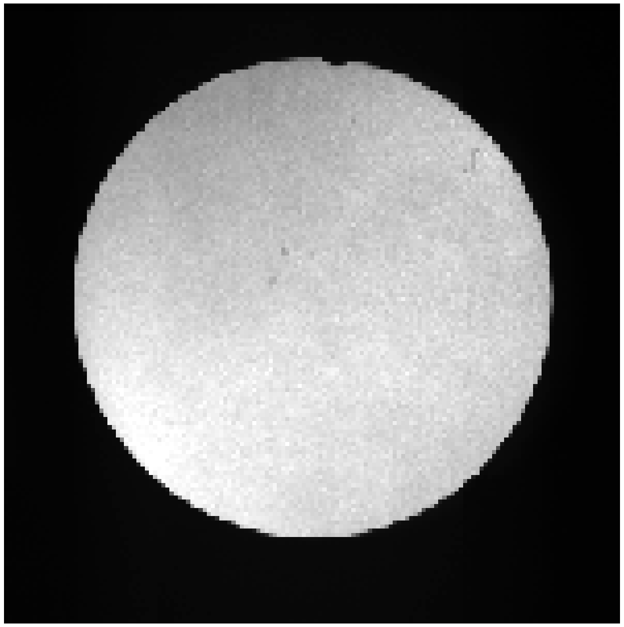
Tests Results

- Breadboard tests results are documented in CIR-RPT-0009
- Laser with apodizer background uniformity across the field:

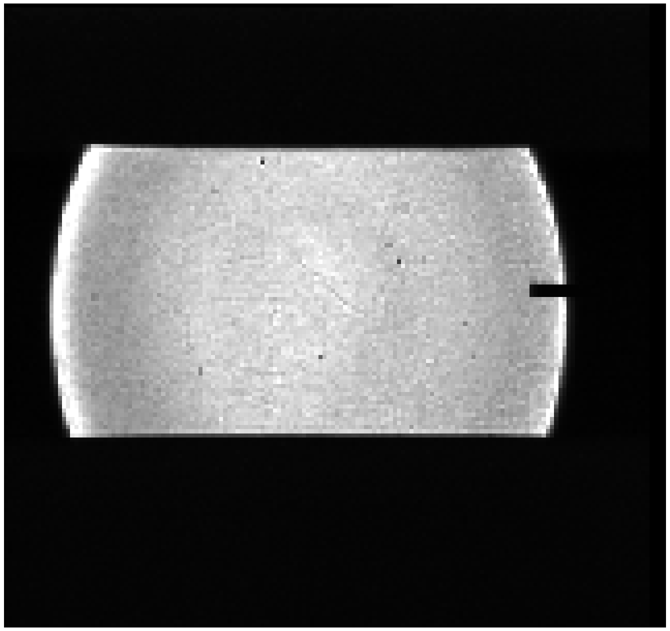
  0.78 (CM-1: 0.59)
- Laser granularity is minimized by controlling the beam spot size on the diffuser, diffuser angle and vibrating the optical fiber

Diagnostics - Illumination Package

Granularity/Uniformity Tests



With Apodizer f/11



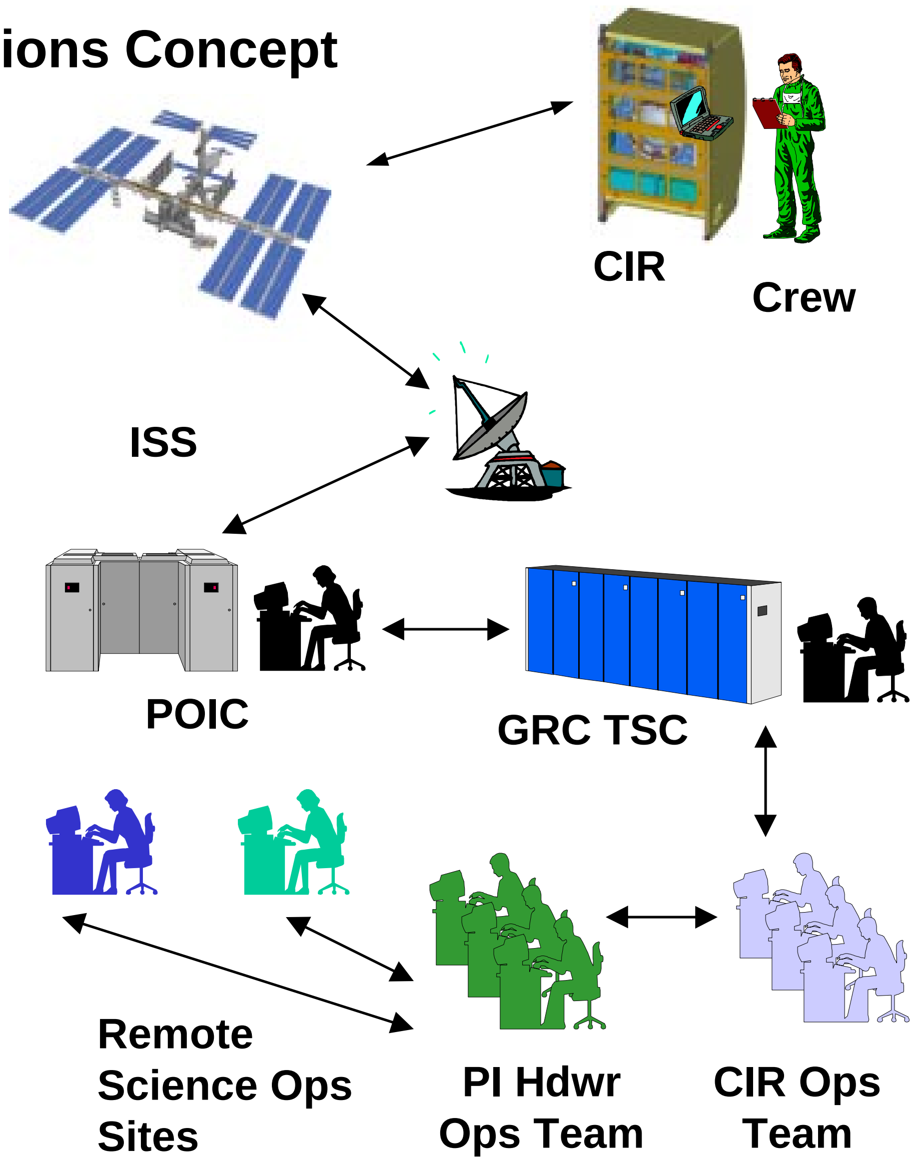
Reference: CM1 rfz000ba

Integration, Operations & Utilization

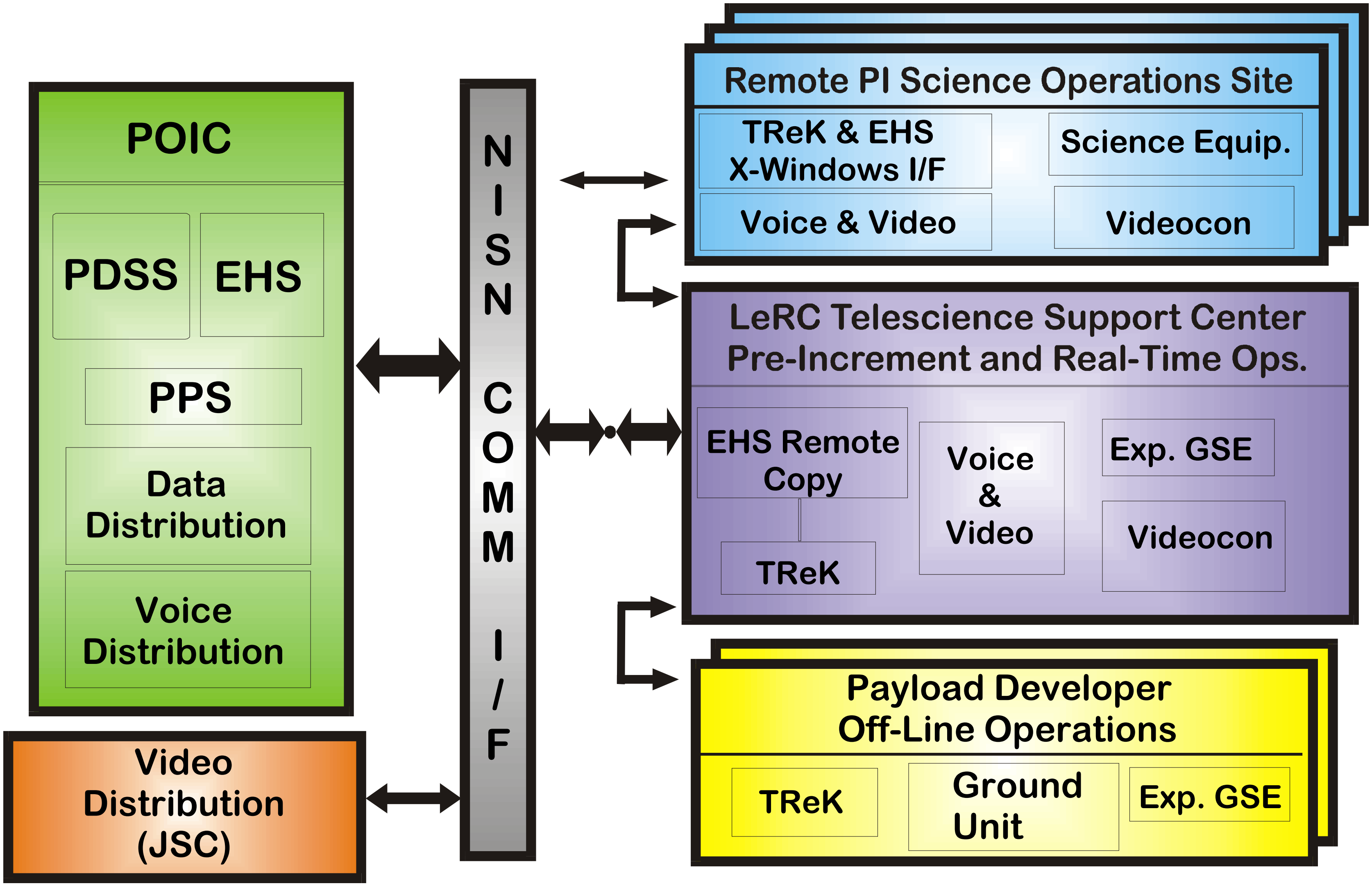
Terry O'Malley
Diane Malarik
Dwayne Kiefer

CIR Operations Concept

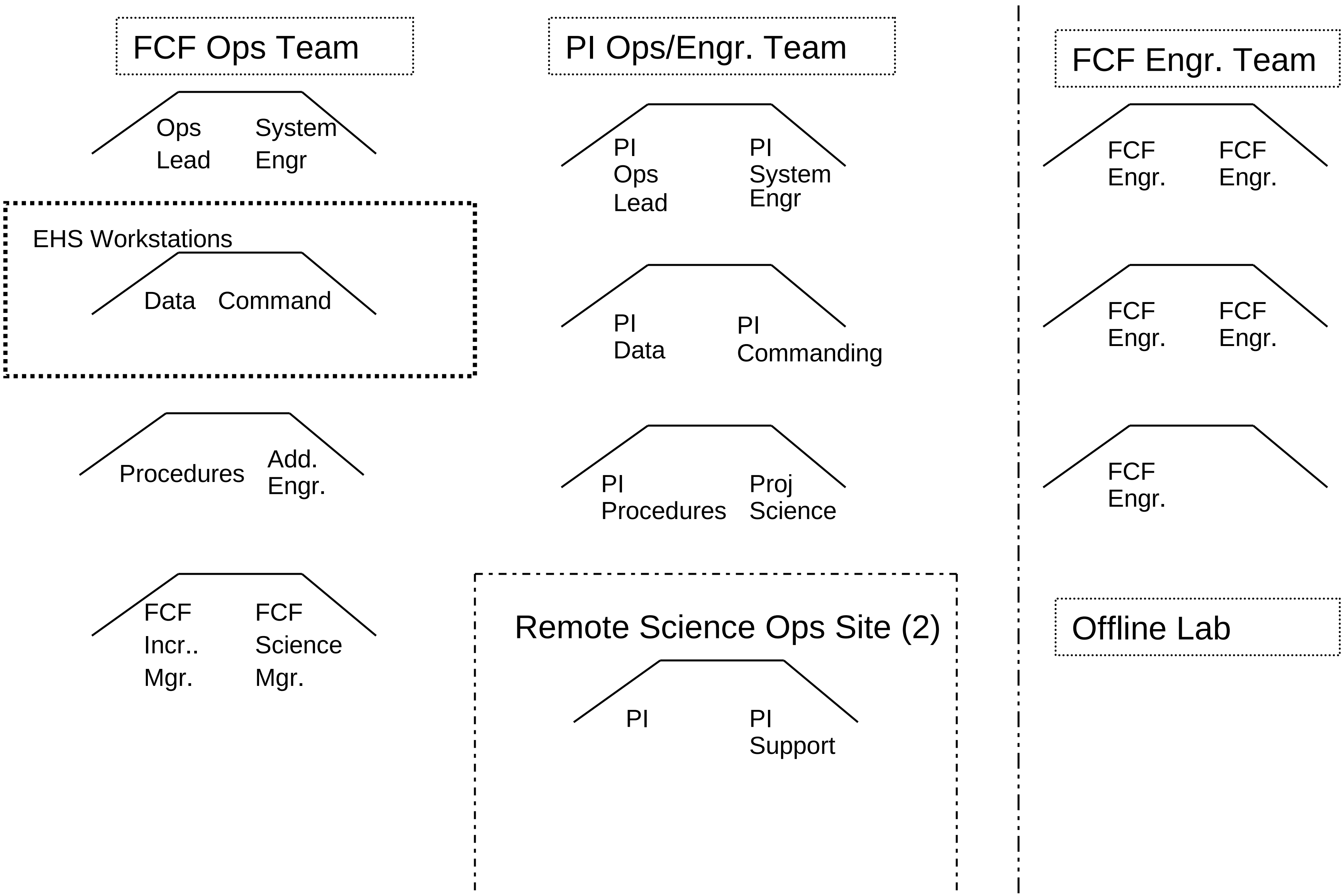
- The CIR is being designed for autonomous, ground tended operations.
- Typically, once the experiment is set up by the crew, it will execute a pre-planned routine.
- Experiment progress will be monitored by the Ops teams and the Ops teams will routinely uplink commands based on the experiment protocol.
- The CIR is being designed for quick and easy set-up and reconfiguration.
- Operations requirements are in Chapter 4 of the SRED
- CIR primary ground operations site is the GRC Telescience Support Center.
- Will host a Remote Copy of the Enhanced HOSC System.



UF3+ Telescience Operations Concept



Possible Ops Console Layout @ UF-3



FCF Increment Execution Functions

Real-Time Functions

- FCF Operations Lead
  - Leads the integrated FCF operations
- Commanding
  - FCF System commanding
  - Command system management
- Data Management
  - Telemetry processing
  - Telemetry monitoring and manipulation
- Timeline/Resource Management
  - Monitor timeline execution vs. plan
- Procedures
  - Monitor crew activity
- FCF Systems Management
  - Monitor health and status of FCF systems
- Science

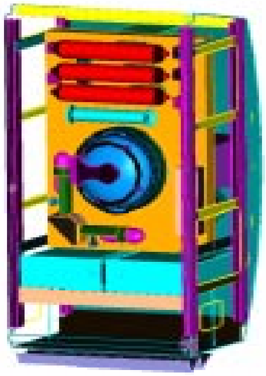
Non Real-Time Functions

- Daily Plan Development
- OCR Tracking
- Resource Management
- Science Management
- Short Term Plan Development

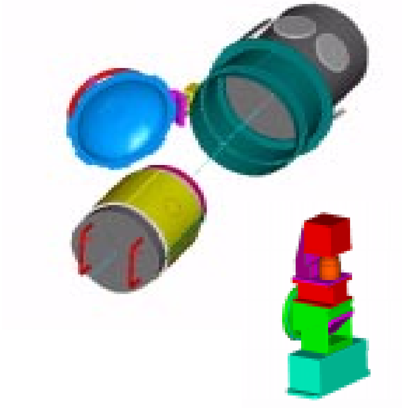
CIR Training Concept

- Primary Crew training will be performed on the Payload Training Center Training Unit.
- Currently planning on developing Computer Based Training modules for Crew training. Can be used for on-orbit training.
- Will use the ISS provided Payload Simulator Environment (PSE) for the PTC Training Unit.
- Part-task trainers will be developed for special skills and/or proficiency training.
- Held Training TIMs #1 & #2 per the Payload Training Implementation Plan for the CIR PTCU
- Developed & reviewed a Draft CIR Simulator Definition Document.

Computer Based Training

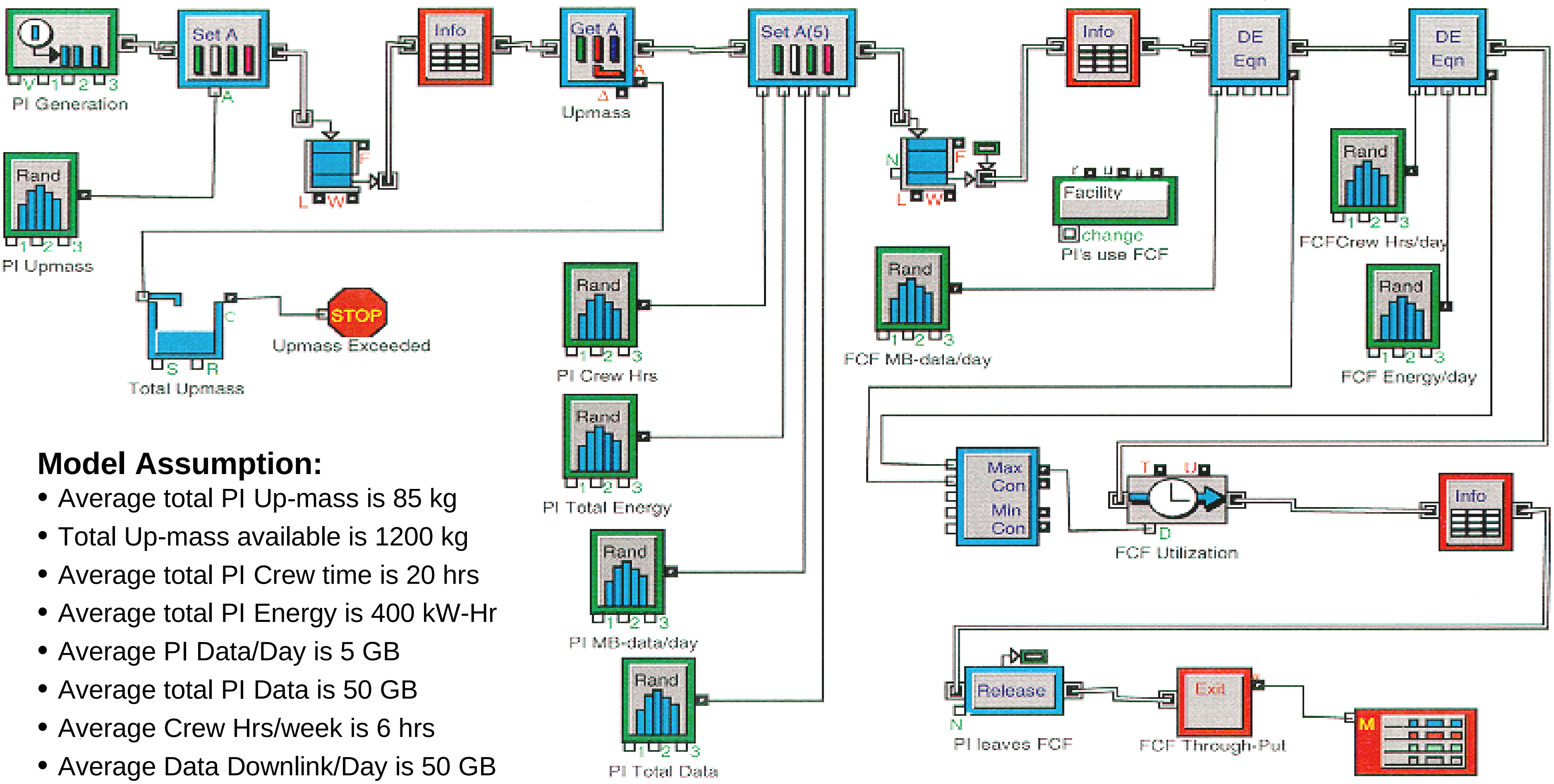


CIR Payload Training Center Training Unit



Part Task Trainers

PI Through-Put Analysis

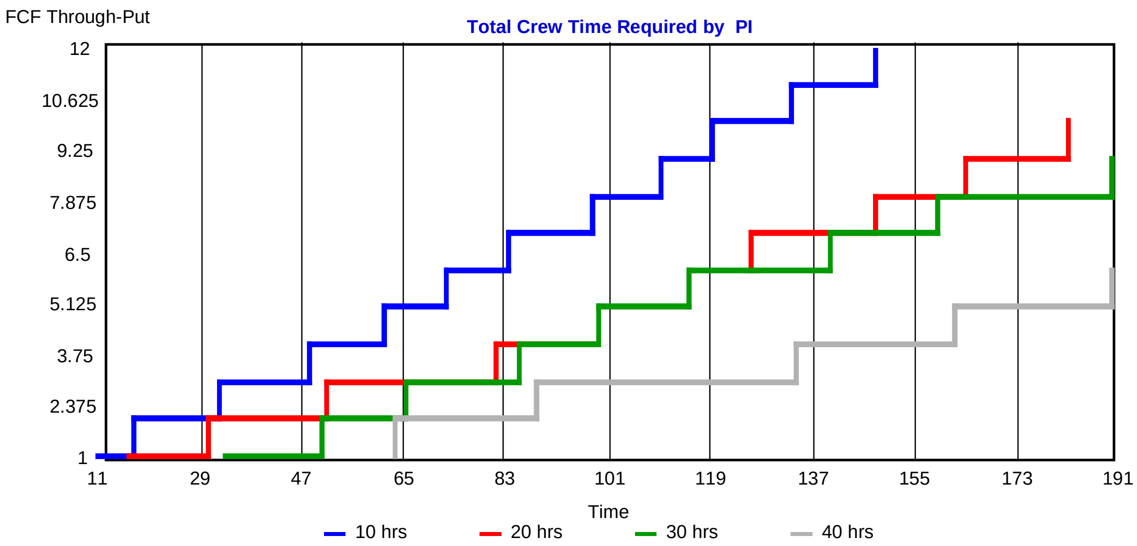


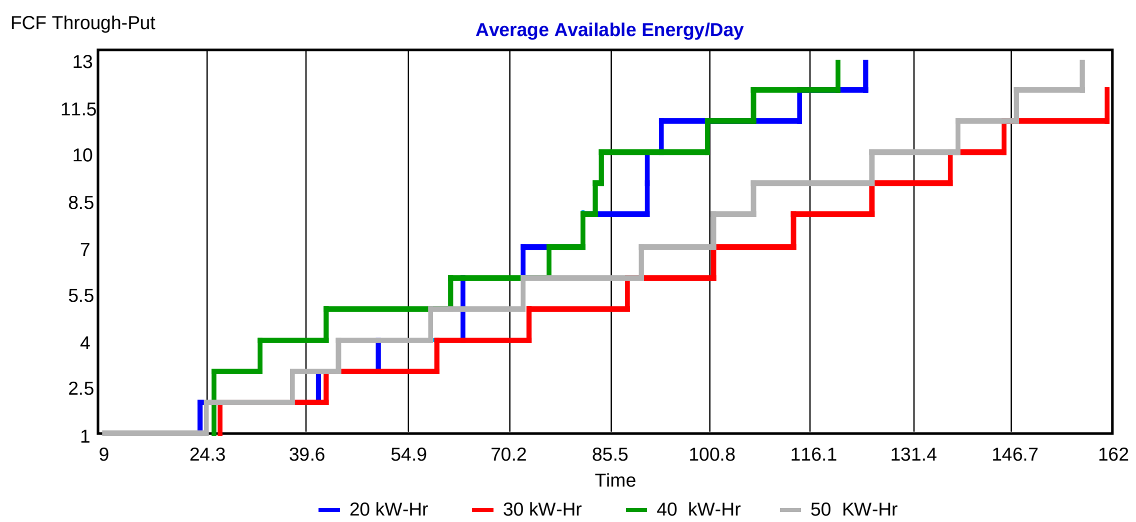
Model Assumption:

- Average total PI Up-mass is 85 kg
- Total Up-mass available is 1200 kg
- Average total PI Crew time is 20 hrs
- Average total PI Energy is 400 kW-Hr
- Average PI Data/Day is 5 GB
- Average total PI Data is 50 GB
- Average Crew Hrs/week is 6 hrs
- Average Data Downlink/Day is 50 GB
- Average total energy/day is 35 kW-Hr
- Model time frame is 8 hrs/day, 4 days/week,
- 4 weeks/month, 12 months/year

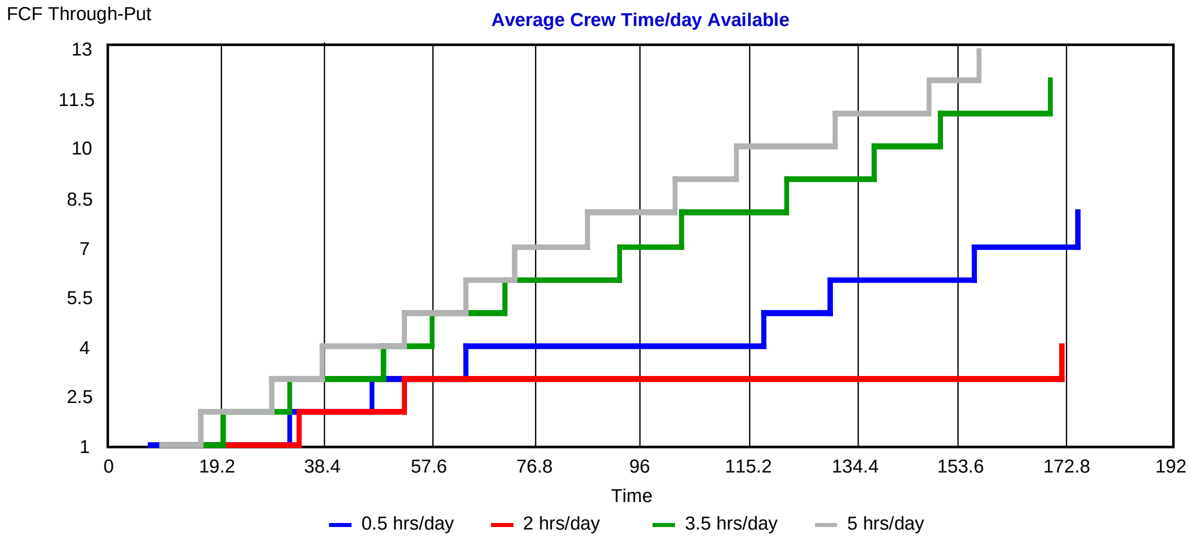
FCF Through-Put Model

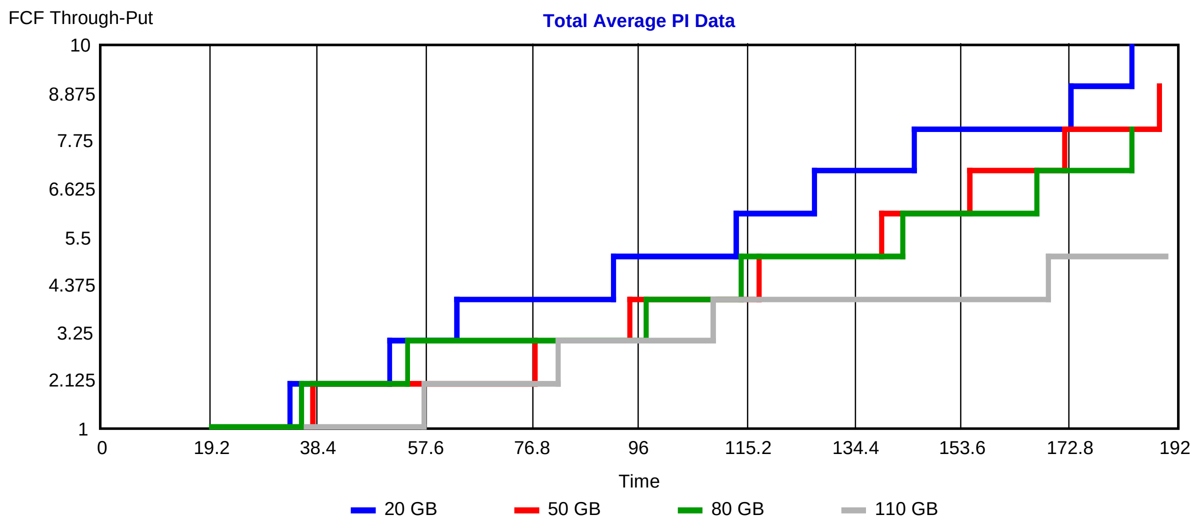
PI Through-Put Analysis
Sensitivity Analysis





PI Through-Put Analysis
Sensitivity Analysis





PI Through-Put Analysis

Findings:

- On average, the FCF can accommodate 10 PI's Per year at steady-state.
- Major items affecting through-put are crew hrs required vs crew hrs available and the ISS data downlink capability.

Upcoming plans for the model:

- Refine model as more mature data becomes available.
- Modeling of thermal requirements and constraints.
- Modeling of ground processing.
- Incorporate the requirements of future PI's.
- Projection of out-year resource and staffing requirements.
    - TSC
    - Ground Processing.
    - Etc.

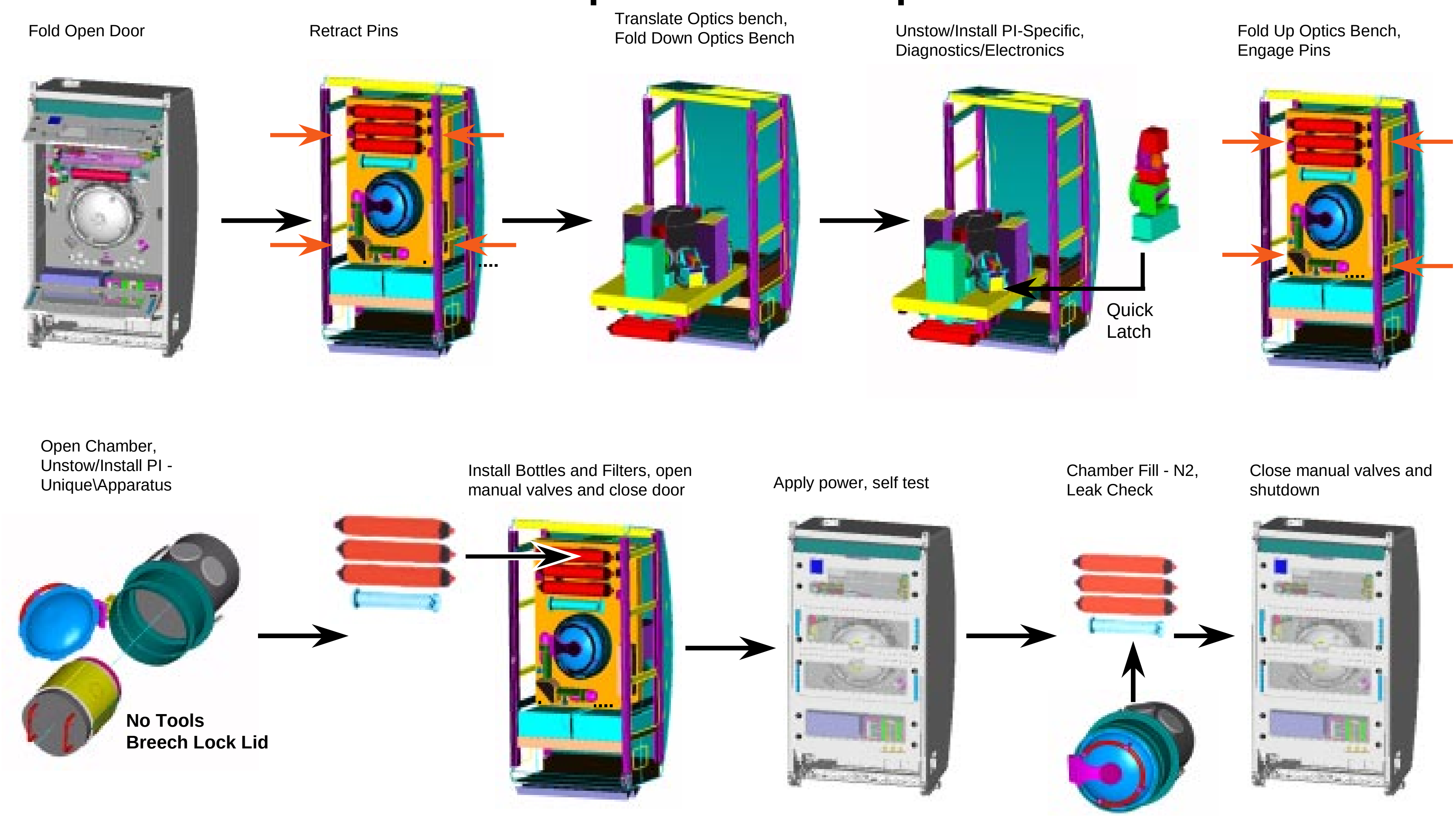
UF-3 Resource Requirements

- There are three distinct elements currently planned for UF-3
  - CIR
  - DCE
  - BCDCE
- The CIR will be launched with an empty Optics Bench, with the cameras, IPPs, and avionics boxes in stowage.
- DCE consists of a CIA, an Avionics box, gas bottles, fuel cartridges, & misc. hardware
- Current concept has BCDCE using the DCE CIA & Avionics, but brings hardware to change out on the CIA, gas bottles, fuel cartridges, & misc. hardware.
- Have done some very preliminary operations analyses to identify tall poles.
- The operational scenario outlined here runs up to 12 test points per day. This yields 33 Gbytes of data
- Limiting resource appears to be downlink

CIR Setup

	Activity	Duration	Crew Time	Elapsed Time	Power	Data	Energy(KwH)
CIR Setup:				0:00	0.00	0.00	
	Open Rack Door	0:05	0:05	0:05			
	Retract Pins	0:05	0:05	0:10			
	Deploy optics bench	0:10	0:10	0:20			
	Install Diagnostics and PI avionics	1:00	1:00	1:20	0.00		
	Stow optics bench	0:10	0:10	1:30			
	Install Chamber Insert	1:00	1:00	2:30			
	Install Gas Bottles	0:30	0:30	3:00	0.00		
	Open Gas supply Manual Valves	0:10	0:10	3:10			0.000
	Close Door	0:05	0:05	3:15			
Startup							
	Apply Power to CIR	0:05	0:05	3:20	539.20	Kbps	0.045
	Self test	0:05		3:25	722.30	Kbps	0.060
Leak check							
	Evacuate Chamber	0:10		3:35	900.80		0.150
	Chamber Fill Leak Check	2:00		5:35	900.80		1.802
	Evacuate Chamber	0:10		5:45	900.80		0.150
	Fill Chamber to one atm	0:20		6:05	900.80		0.300
	Close manual valves and shutdown	0:10	0:10	6:15			

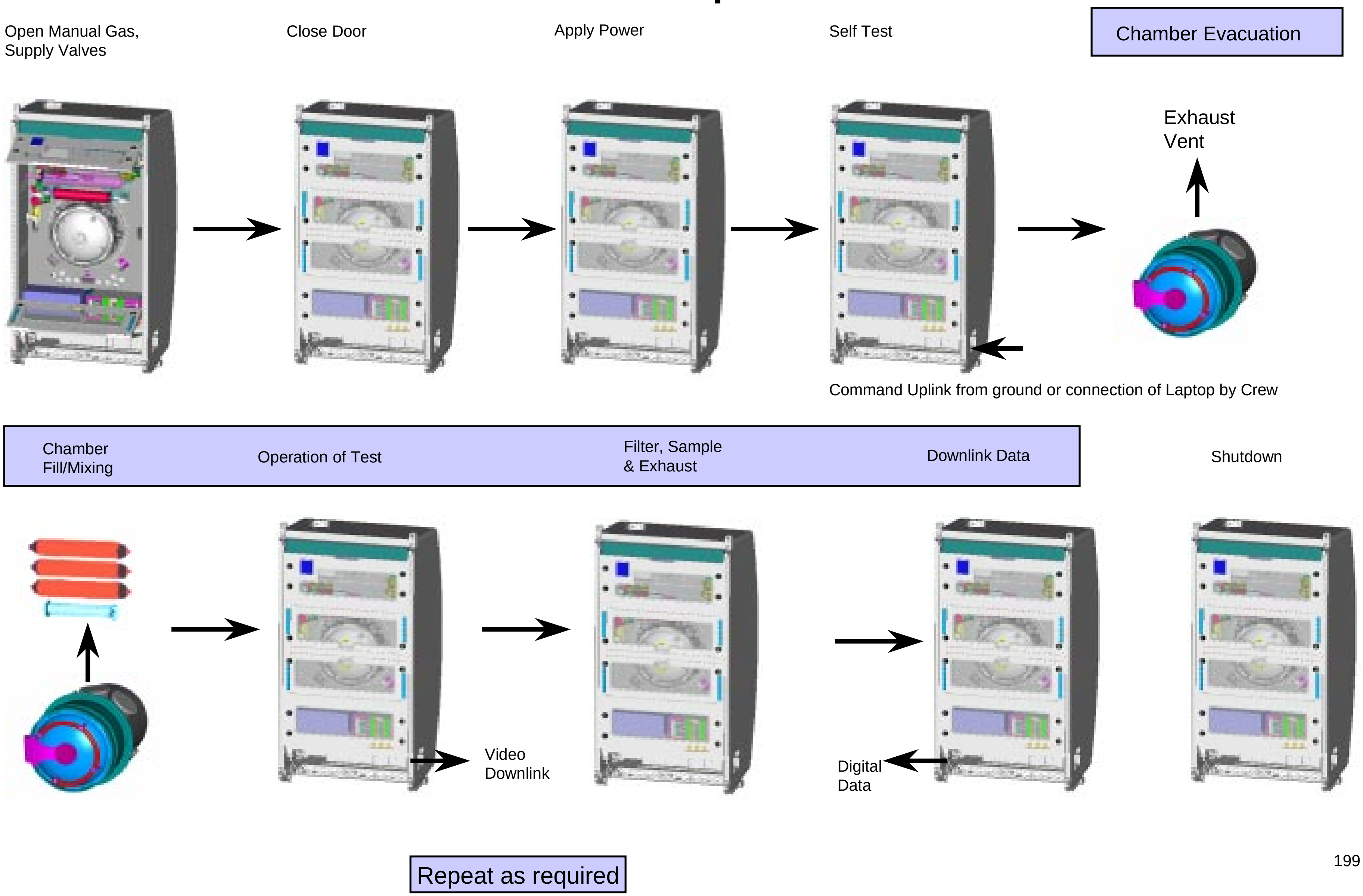
CIR Operations - Setup



Experiment Execution Timeline Example

Science Execution Typical Day							
	Activity	**Duration**	**Crew Time**	**Elapsed Time**	**Power**	**Data**	**Energy(KwH)**
DCE Startup							
	Open Manual Valves	0:10	0:10	0:10			
	Apply Power to CIR	0:05	0:05	0:15	539.20	Kbps	0.045
	Self test	0:05		0:20	722.30	Kbps	0.060
	Evacuate Chamber	0:10		0:30			
Experiment Setup							
	Fill Test Chamber	0:20		0:40	900.80		0.300
	Verify Diagnostics	0:15		0:55	2523.40		0.631
Execute Experiment							
	Command ignition	0:01		0:56	2523.40		0.042
	Observe Phenomena	0:13		1:09	2523.40	2752.512	0.547
	Verify Complete	0:01		1:10	2523.40		0.042
Repeat Experiment (2)		0:15		1:25	2523.40	2752.512	0.631
Repeat Experiment (3)		0:15		1:40	2523.40	2752.512	0.631
Recycle Test chamber							
	Clean up and sample	0:30		2:10	871.20		0.436
Experiment Setup (chamber fill)		0:20		2:30	900.80		0.300
Execute Experiment (4)		0:15		2:45	2523.40	2752.512	0.631
Execute Experiment (5)		0:15		3:00	2523.40	2752.512	0.631
Execute Experiment (6)		0:15		3:15	2523.40	2752.512	0.631
Recycle Test chamber		0:30		3:45			
Experiment Setup (chamber fill)		0:20		4:05	900.80		0.300
Execute Experiment (7)		0:15		4:20	2523.40	2752.512	0.631
Execute Experiment (8)		0:15		4:35	2523.40	2752.512	0.631
Execute Experiment (9)		0:15		4:50	2523.40	2752.512	0.631
Recycle Test chamber		0:30		5:20	871.20		
Experiment Setup (chamber fill)		0:20		5:40	900.80		0.300
Execute Experiment (10)		0:15		5:55	2523.40	2752.512	0.631
Execute Experiment (11)		0:15		6:10	2523.40	2752.512	0.631
Execute Experiment (12)		0:15		6:25	2523.40	2752.512	0.631
Recycle Test chamber		0:30		6:55			
Data Transfer and Downlink							
	Total science data (MB)		33030.14				
	Downlink time at 5 mbps		14.68006				
Downlink							
	Command to downlink	0:01		0:01	509.80		0.008
	Downlink science data	14:40		14:41	509.80		7.484

Nominal PI Operations



CIR/DCE Launch Stowage Requirements

Since the CIR and DCE hardware will be transported to orbit stowed outside of the rack it will require additional stowage volume. The tables summarize our launch & stowage requirements for UF-3

Launch Volume DCE Hardware

Equipment	Mass (kg)	Dimensions (mm)	Volume (m^3) *
Exhaust Filters	4.7	170 x 295 x 495	0.036
Illumination Package	13	270 x 221 x 470	0.040
PI Unique Electronics	10.3	255 x 360 x 330	0.043
Gas Bottles (4) - 2.25 Liters	30	101 ∅ x 559	0.026
Maintenance Items	10	254 x 254 x 254	0.016
Additional Fuel Syringes (7)	14	170 x 102 x 102	0.017
PI Unique Hardware (1)	40	400 ∅ x 635	0.114
Total	**122**		**0.292 m^3**

Launch Volume BCDCE Hardware

Equipment	Mass (kg)	Dimensions (mm)	Volume (m^3) *
Exhaust Filter	4.7	170 x 295 x 495	0.036
Gas Bottles (4) - 2.25 Liters	30	101 ∅ x 559	0.026
Maintenance Items	10	254 x 254 x 254	0.016
Additional Fuel Syringes (7)	14	170 x 102 x 102	0.017
Total	**58.7**		**0.095 m^3**

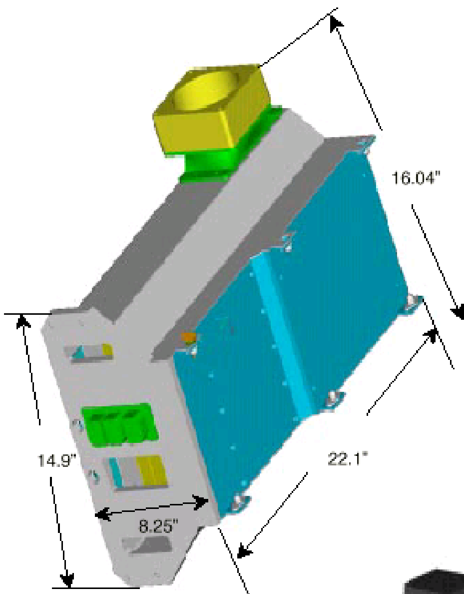
Launch Volume CIR Equipment

Equipment	Mass (kg)	Dimensions (mm)	Volume (m^3)*
Color Camera	8.3	290 x 231 x 400	0.038
Image processing Pack (2)	43	255 x 360 x 580	0.076
High Frame Rate Camera	14.7	260 x 231 x 500	0.043
HiBM	11.7	270 x 221 x 470	0.040
Low Light Level Camera (2)	28.6	290 x 231 x 400	0.077
Illumination Package	13	270 x 221 x 470	0.040
FOMA Control Unit	10.3	255 x 360 x 330	0.043
Maintenance supplies - GC Bottles - Columns - Misc.	20	170 x 285 x 495	0.034
Checkout gas bottles (2)	15	101 ∅ x 559	0.007
Total	**164.6**		**0.398 m^3**

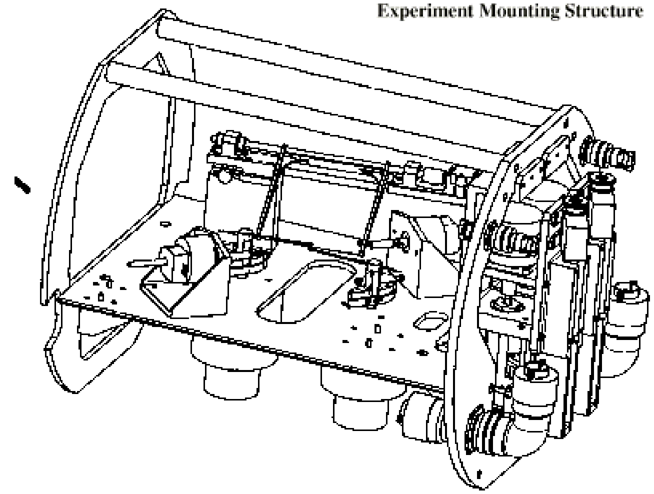
*** Includes 70% stowage efficiency**

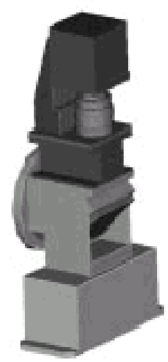
Sample Stowage Items

CIR Image Processing Package (IPP)



Droplet Combustion Experiment II Experiment Mounting Structure





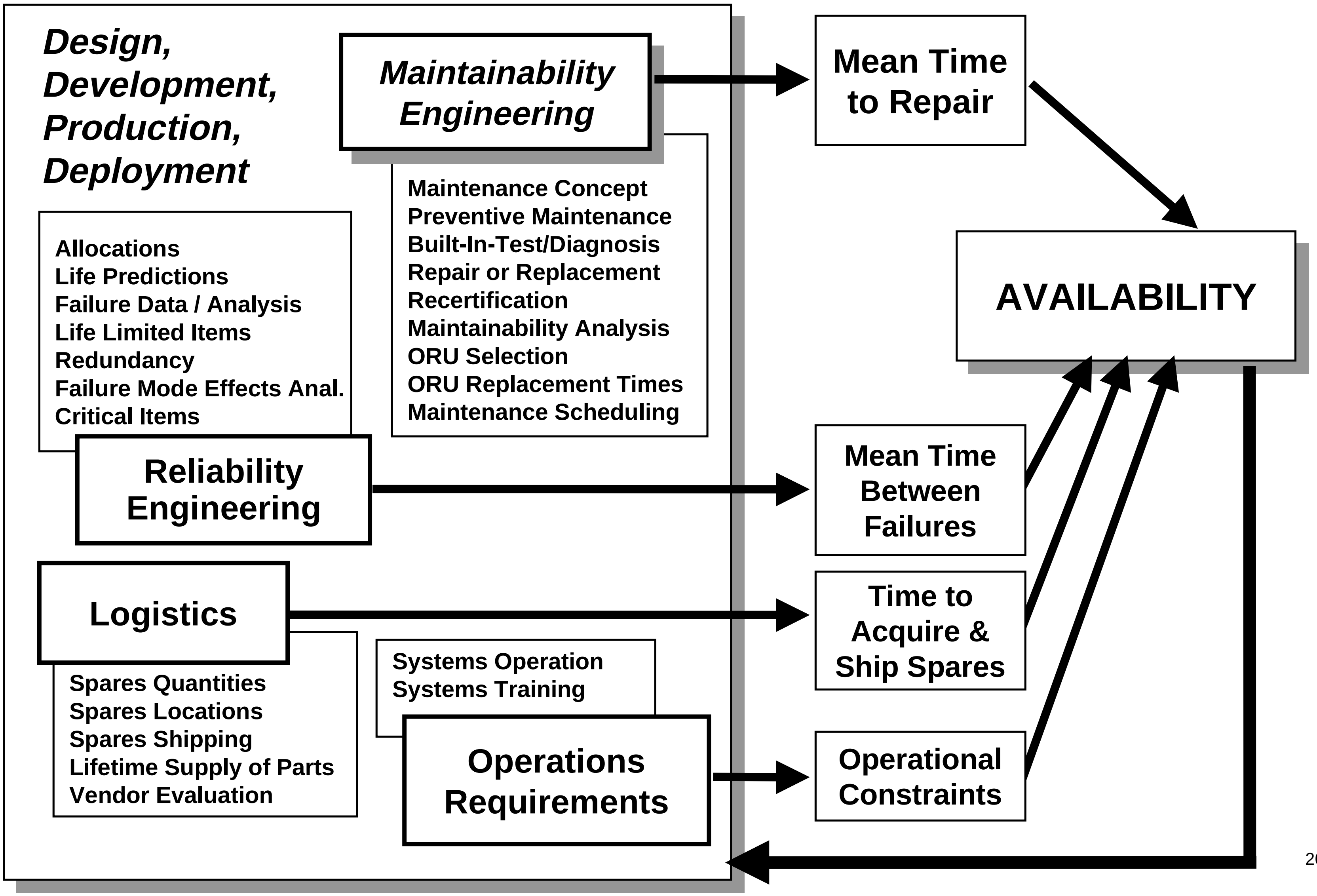
Typical Diagnostic

Gas Bottles & Filter Cartridges

Reliability/Maintainability Requirements

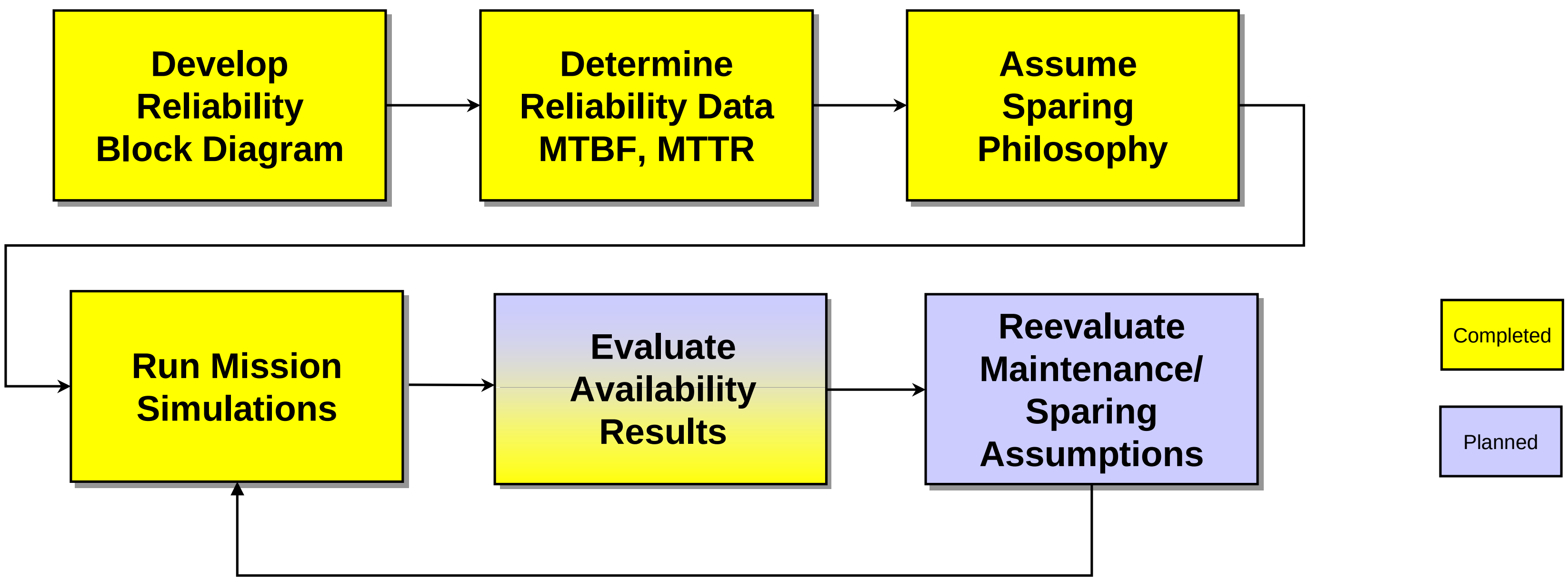
- **Reliability and Maintenance requirements derived from the GRC Standard Assurance Requirements and Guidelines for Experiments (SARGE) section 7.**
- **Additional requirements included in the FCF System Specification and SSP Documents**
  - FCF flight segment shall have an availability of 92% over it's lifetime.
  - Additional maintenance requirements detailing use of tools, redundancy, etc are contained in the draft specifications and are derived from SSP 50005 and SSP 57000
- **Availability Requirements will be verified by reliability and Operational Availability analysis**
- **Lower level maintenance requirements will be verified by demonstration or analysis as appropriate.**

Maintainability and Availability Process Flow



Availability Analysis Process

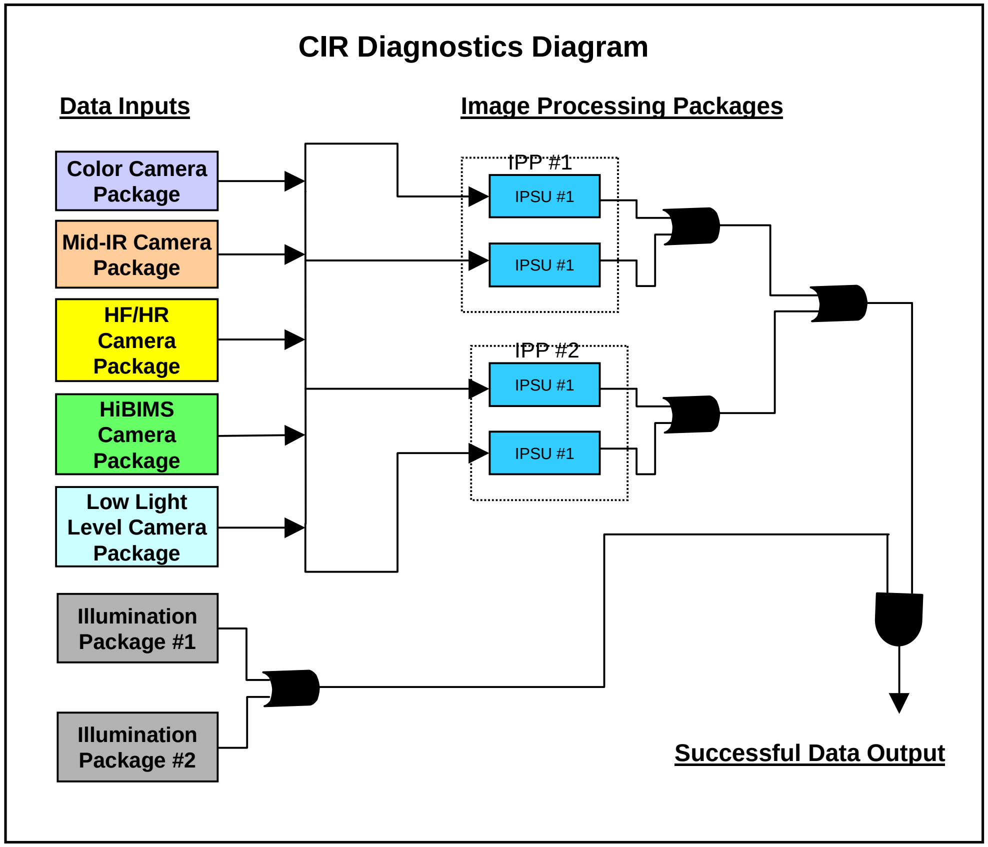
- An Operational Availability Model has been developed using RAPTOR
- Reliability data is a combination of preliminary hardware assessments and data derived from PRICE H model.
- Model was run using both generous and limited sparing
- Model demonstrates CIR availability of between 93.1% (generous sparing) and 69.9% (limited sparing)



Failure Modes and Effects Analysis (FMEA)

- A preliminary FMEA was compiled
  - Presented the ground rules for the analysis
  - Provided package breakdown and functional block diagrams for subsystems
  - Several analysts created the work sheets
  - Provided preliminary work sheets with a list of items, functions, failure modes, criticality categories, local effects, system effects, and potential causes for most subsystems
- FMEA work sheets were used by safety to check hazard analysis
- FMEA work sheets were used by designers to check redundancy and need for design changes.

Typical Functional Block Diagram



CIR Supporting Engineering Status

- **Reliability and Maintainability Plan in review.**
- **Preliminary Failure Modes and Effects Analysis completed**
- **CIR Availability Model constructed.**
  - **Model tested using MTBF data from Price H Model.**
  - **Sparing alternatives being evaluated.**
  - **Data fidelity will increase as design matures.**
- **FCF Integrated Logistics Support Plan in review**
- **Preliminary LSA for CIR completed**
  - **Includes ORU candidate list as well as intermediate level maintenance assessment**
  - **Preliminary Repair Level Analysis**
  - **Maintenance task assessment for On-orbit maintenance Tasks**
- **Bottoms up reliability assessment is planned post PDR**
- **Maintainability requirements will be revised and reviewed post PDR**
- **Quality Assurance plan is ready for baselining**
  - **Complies with ISSP Q/A requirements defined in SSP 41173**

Ground Segment

Objective:

Provide ground support equipment and facilities required to support the CIR development and operations.

Provide facilities and equipment to support integrated testing between payload experiment equipment and CIR.

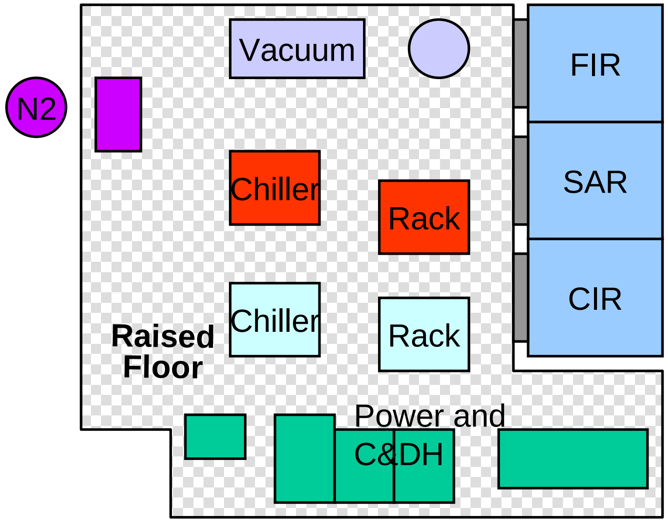
Major Pieces of GSE:

Payload Rack Checkout Unit (PRCU) - Simulates all ISS interfaces

Suitcase Test Environment for Payloads (STEP) - Simulates ISS Command and Data Handling

Rack Handling Adapters (RHA) - Supports the flight ISPR's

Rack Shipping Containers - Used to provide physical and environmental protection of flight racks during transportation



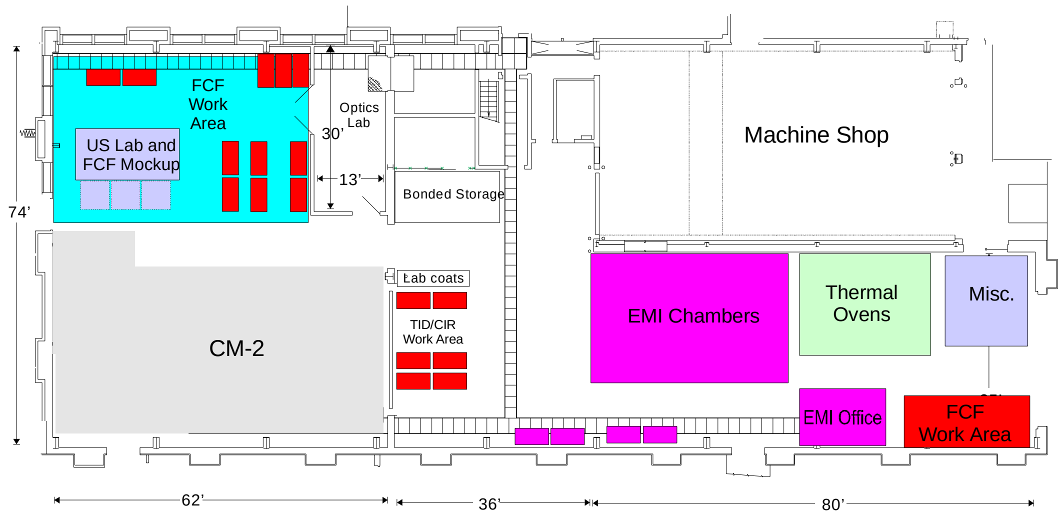
PRCU

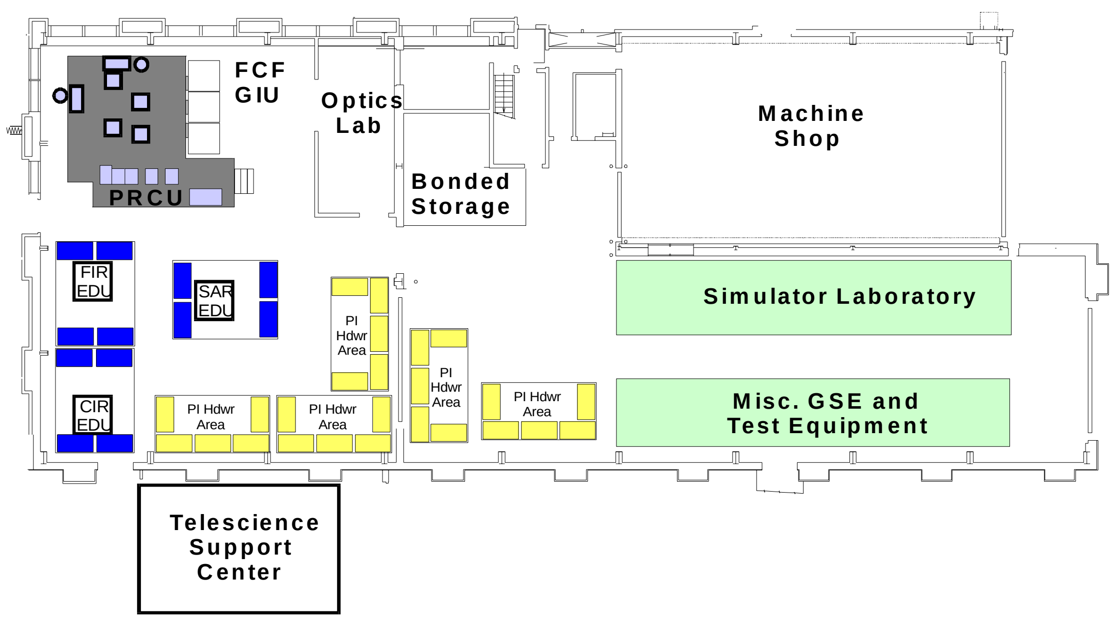
- The PRCU, to be located in Bldg. 333, simulates the Moderate Temperature Cooling Loop, Low Temperature Cooling Loop, Vacuum Resource System, Vent, Nitrogen Supply, Power, and Command and Data Handling.
- Installation scheduled for Fall 1999.
- Will be used for operating the Engineering Models (EM's), Flight Units, and Ground Integration Units (GIU's).

Ground Facilities

Building 333 - March 1999

- Addition to nearby building currently under construction to house EMI chambers and thermal ovens.





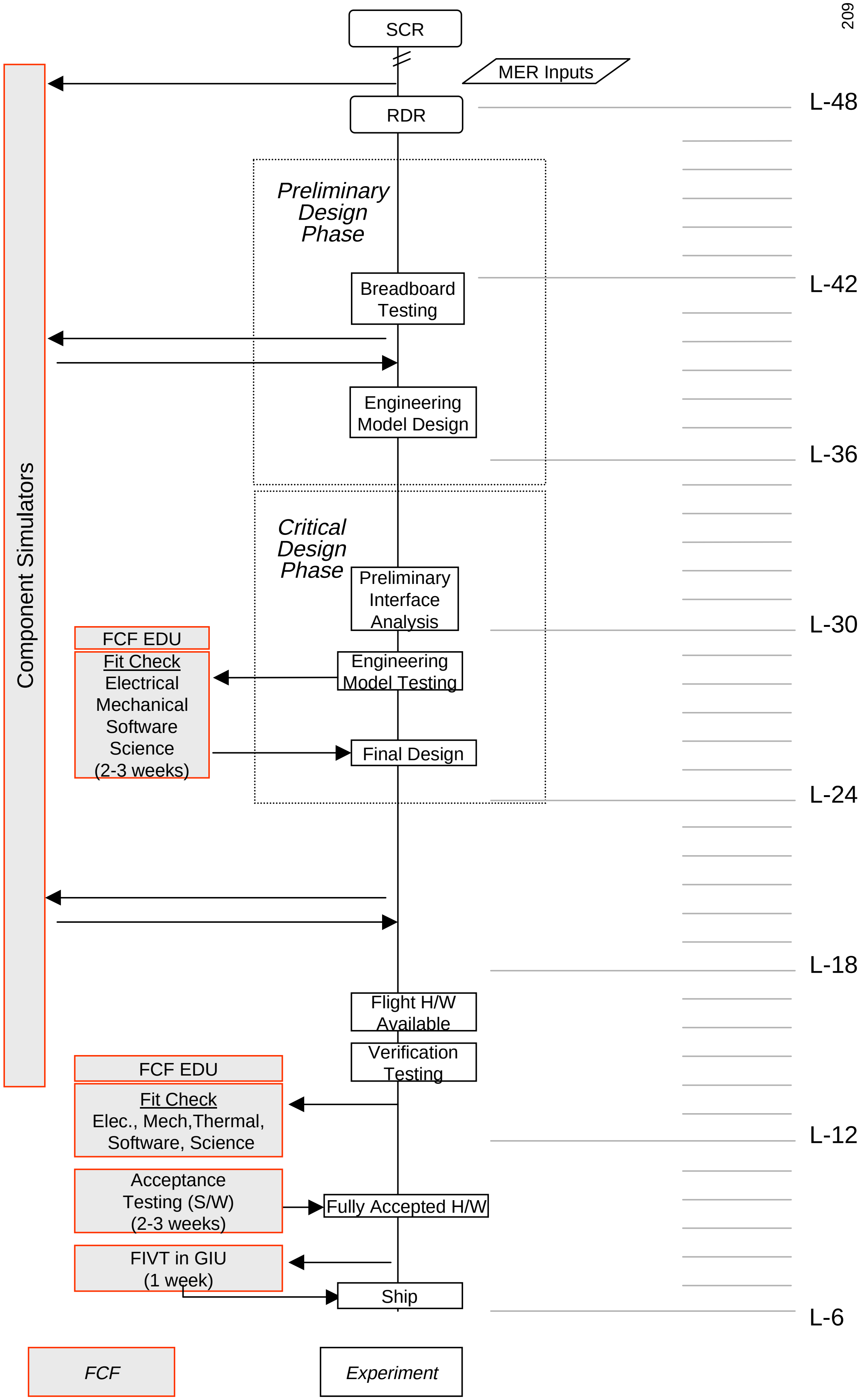
Building 333 - Long Term

- FCF will eventually have ~10,000 square feet to perform ground processing operations at GRC.

Space Station Fluids and Combustion Facility

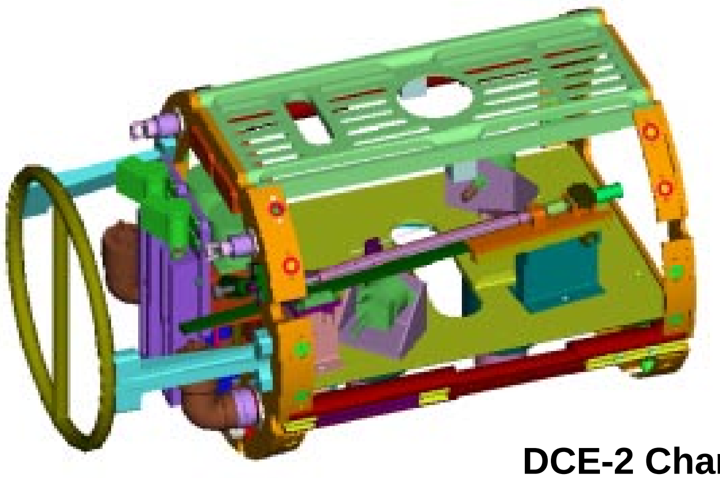
FCF to Experiment Physical Integration Concept

Fluids & Combustion Facility
Glenn Research Center

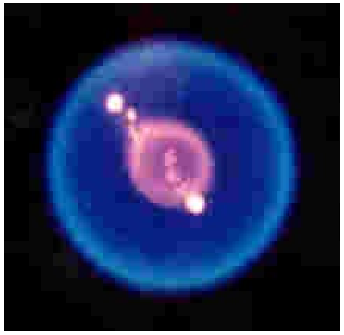


CIR - DCE-2 Integration

- Established (9/98) a CIR - DCE-2 Integration team to work interface and integration issues, in lieu of formal interface and integration documentation.
- Developed an Interface Technical Agreement, which is a precursor to a formal ICD.
- Over 40 CIR/DCE interface issues were resolved.
- Performed a bench-top test between the EPCU engineering model and the DCE simulator. Both teams gained a lot from the tests.
- Developed a top level CIR-DCE-2 integration schedule.
- DCE-2 held a Investigation Continuation Review on 2/24/99



DCE-2 Chamber Insert Apparatus



Burning Droplet from DCE, flown on the Microgravity Science Lab

Component Simulators

- **Interface Simulators**

  Electrical Power Control Unit (EPCU)

  Input/Output Processor (IOP)

  Image Processing Storage Units (IPSU)

Used to simulate interfaces that are complex and require extensive testing, usually followed by payload experiment redesign.

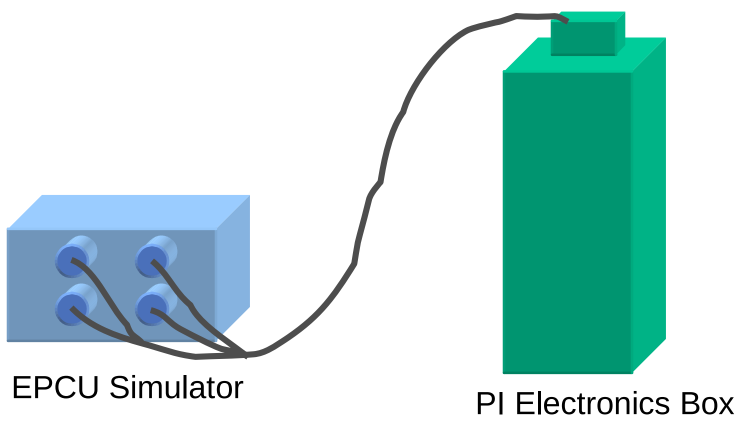
- **Configurable Equipment Simulators**

  Diagnostics (drop rig compatible)

  Fuel Oxidizer Management Assembly (FOMA) and Chamber

  Used to optimize configuration, test sequence, parameter selection, etc.

Component Level Interface Testing



- FCF/CIR applications engineers assist in the use of the simulators.
- Allows several PD’s to conduct interface testing on different subsystems simultaneously, early in their development cycle.

CIR Ground Units

Experiment Development Unit (EDU)

- High fidelity engineering model, that can be used to conduct system level integrated testing with the payload .
- PD's define objectives, Facility operates the hardware.
- Initial testing with Payload engineering hardware at L-24
  - Interface verification (mechanical, electrical, software, thermal, fluid)
  - Preliminary science acquisition
  - Preliminary configuration and parameter selection
  - Test sequence identification
  - Crew procedure validation
- Payload Flight Hardware Testing at L-15 to 9
  - Interface verification (mechanical, electrical, software, thermal, fluid)
  - Ground science data acquisition
  - Final configuration and parameter selection
  - PI familiarization training, using a flight-like user interface
  - Payload Acceptance Testing

Ground Integration Unit (GIU)

- Identical to Flight Unit, except for rack itself will be aluminum, rather than composite.
- Will be used to support on-orbit troubleshooting and Final Interface Verification Testing (FIVT)of Payload equipment and FCF upgrades.
- FIVT to occur during L-9 to 7 timeframe. Duration: 1 week/payload.
- Facility defines test conditions, writes test plan, and conducts test, with PD concurrence.
- Analogous to KSC Level IV testing.
- H/W and S/W configuration frozen after FIVT.

CIR Ground Unit

CIR to ISS Interfaces

- The FCF initiated PIRN 57217-NA-0001, Deviation Request For On-Orbit Temporary Protrusion Exceedance
- The PIRN was revised to 57217-NA-0001A and **APPROVED** by the PCB on 3/31/99
- The PIRN was approved for the following:
  - Translation and rotation of the optics bench
  - Protrudes on a temporary basis (~1hour)
  - Protrusion can be rapidly restowed (~1 min)

Payload Engineering Integration Exception Analysis of PIRN 57217-NA-0001A — Page 14 of 28

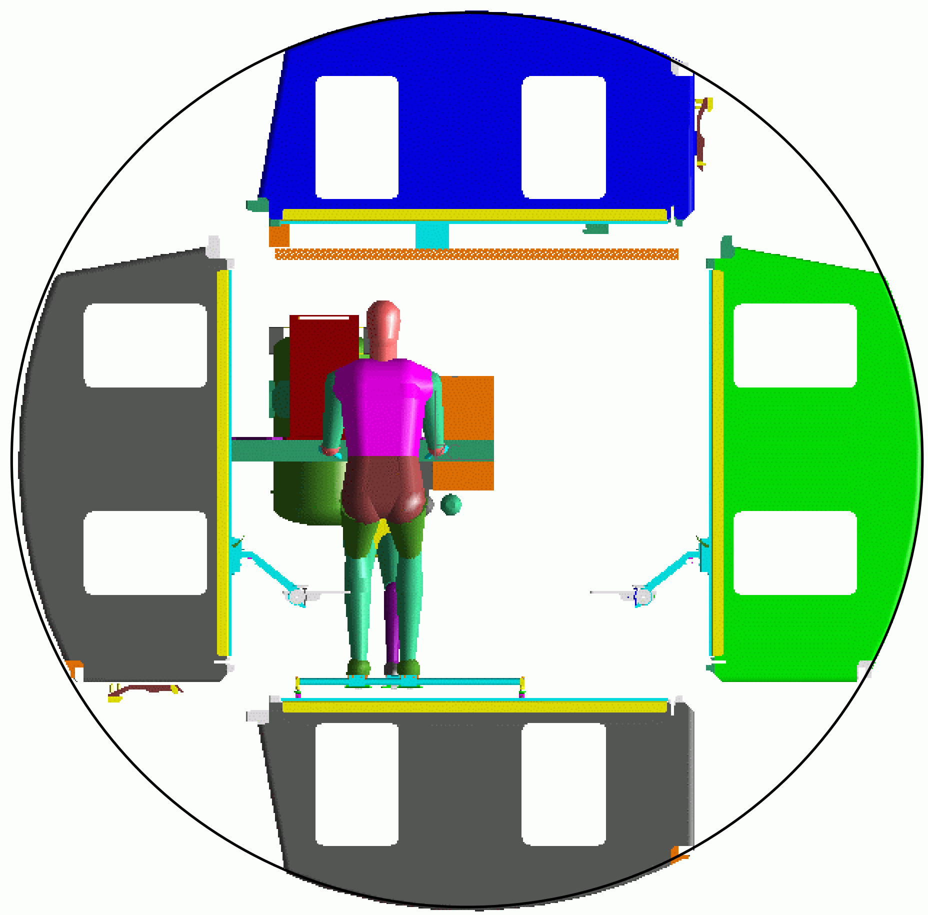
Payload Engineering Integration Exception Analysis of PIRN 57217-NA-0001 Deviation Approval Request for On-Orbit Temporary Protrusion Exceedance

March 2, 1999

Prepared by Boeing
James A. Mayfield

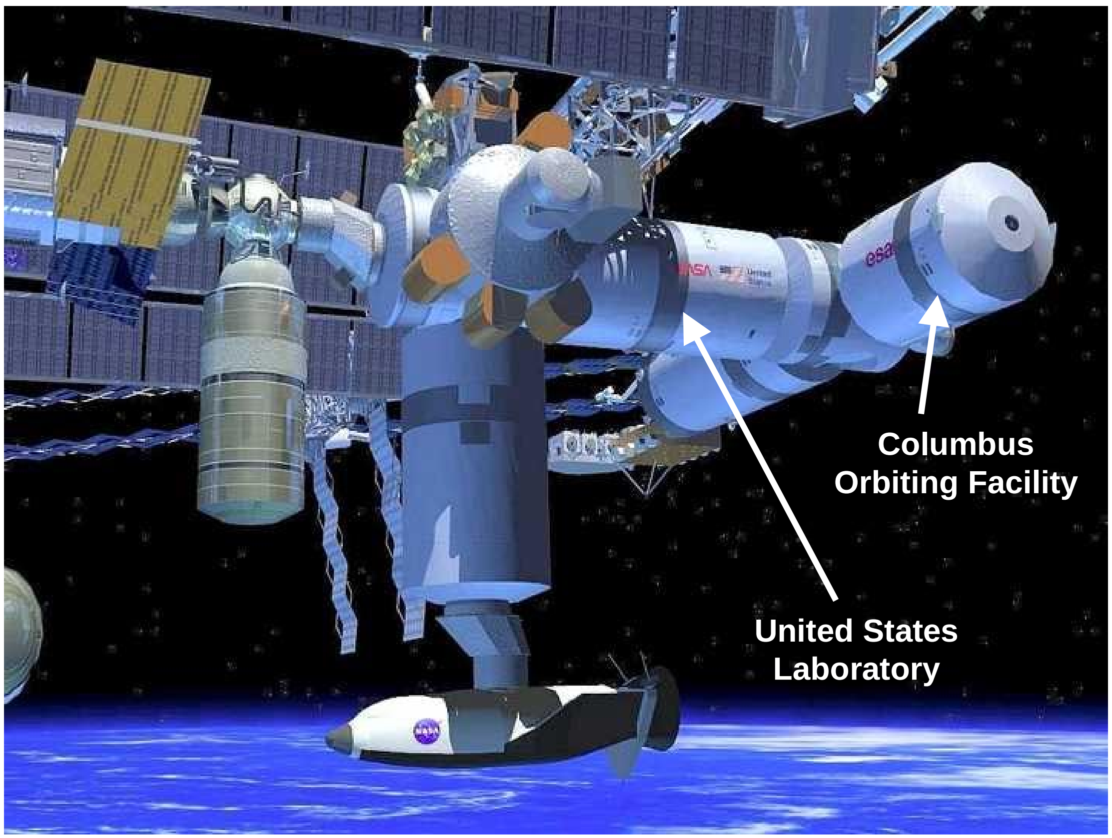
INTERNATIONAL SPACE STATION

BOEING



CIR to ISS Interfaces

- The ISSP has directed the FCF to assess it's compatibility with the Columbus Orbiting Facility (COF) in addition to the US Lab



- Outstanding Incompatibility Issues include:
  – ITCS Pressure Drop: The pressure differential of the integrated rack within the COF is required to be 5.8 ± 0.2 psi at the integrated rack's maximum required flow rate. The CIR is designed to meet the ICD defined Pressure Drop curve for the US Lab.
  – The COF limits a train (4 ISPRs in a row) to 3200 kg. The on-orbit mass of each FCF rack could be 1000 kg. The US Lab on-orbit limit is 1000 kg per ISPR location.
  – The Vent System of the COF may have materials in it that are incompatible with gasses that could be vented in the US Lab
  – Rack To Rack Umbilicals assessment was for the US Lab only.

CIR to ISS Interfaces

- SSP 57000-NA-0110E, Microgravity Requirements and Verification TBDs, limits the amount of disturbance that CIR can induce into the space station environment. This requirement imposes a microgravity level that the CIR may be unable to meet with the current design.
- Potential Cost impacts have been submitted to the MRPO and ISSPO
- The FCF is currently supporting the MRPO PIRN coordination activities
- Analysis and test are planned to quantify cost and schedule impacts

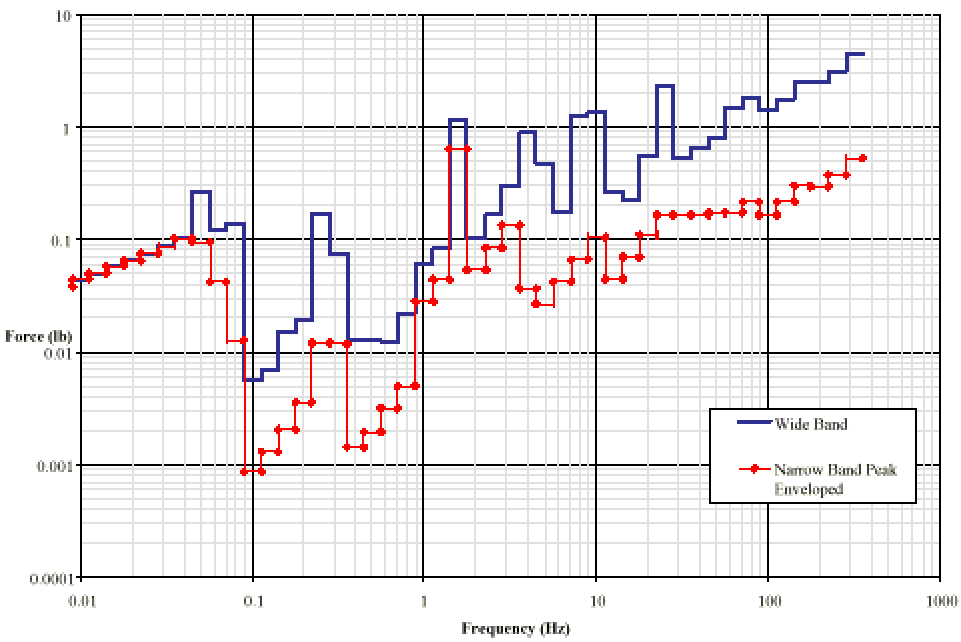


Figure 3.1.2.2-1 Allowable One-Third Octave Interface Forces for Integrated Racks and Non-Rack Payloads

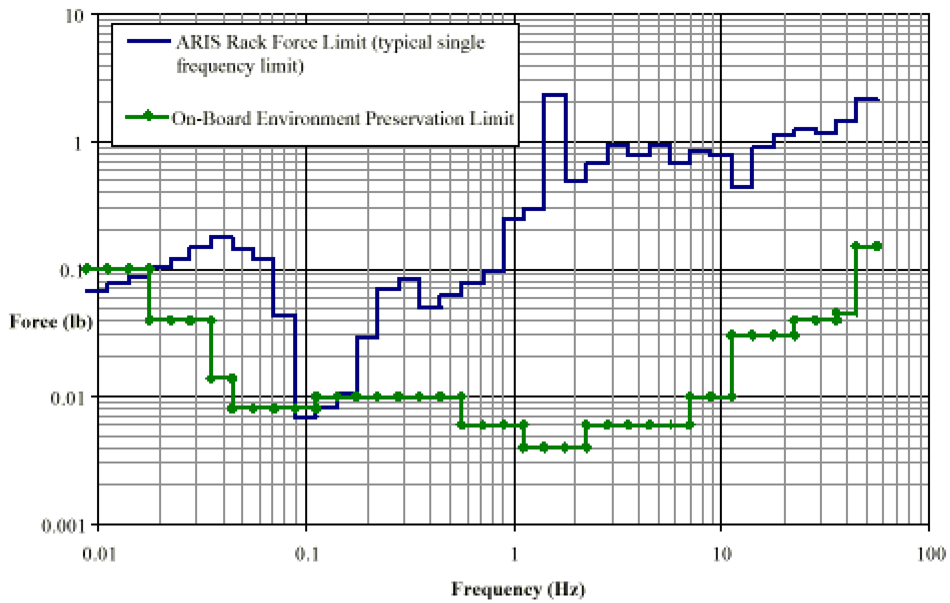
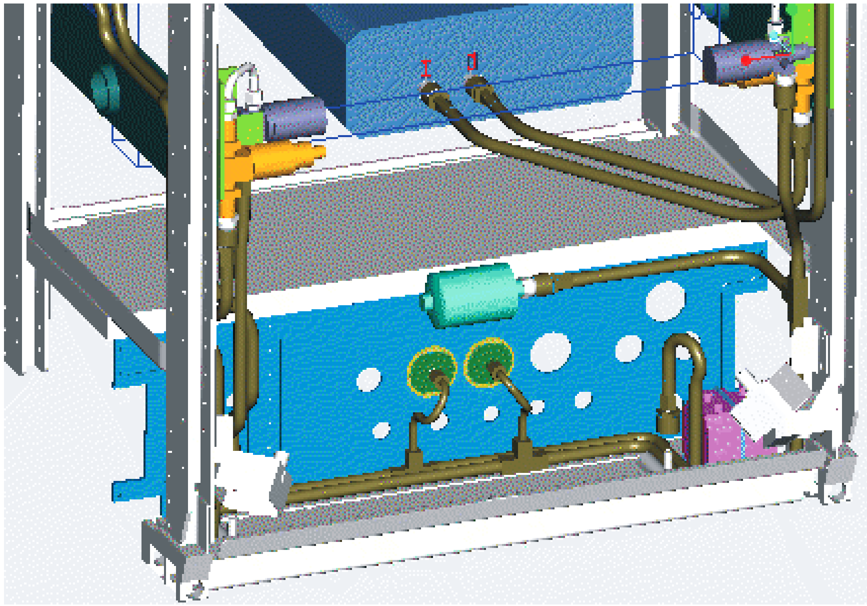


Figure 3.1.2.5.1-1 ARIS On-Board Disturbance Limits

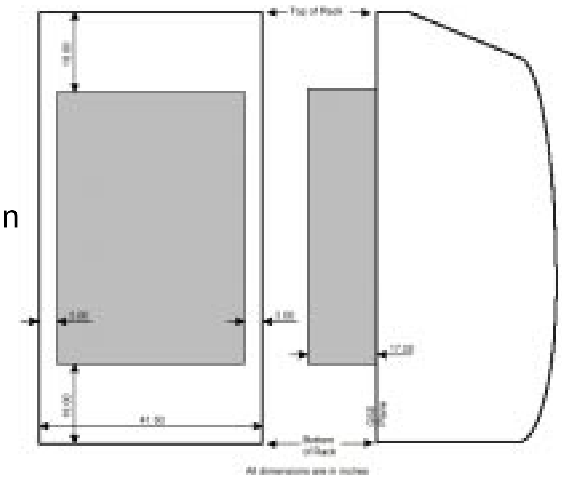
CIR to ISS Interfaces

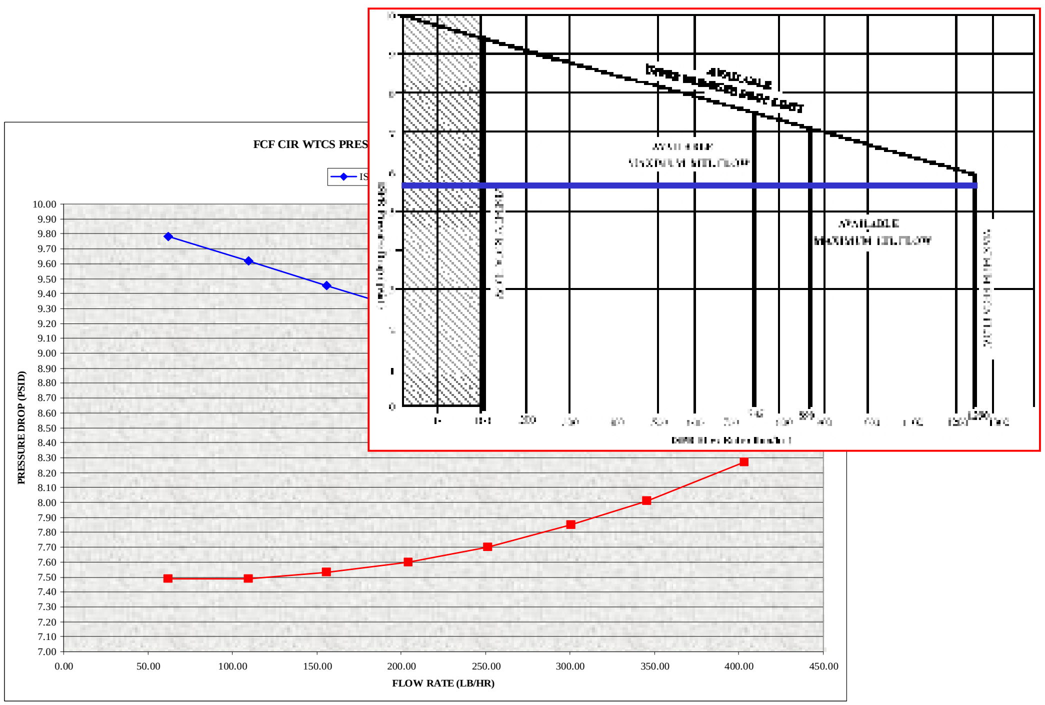
- SSP 57000-NA-0132A, Acceptable Gases For Vacuum Exhaust System, (co-authored by CIR Exhaust Vent Lead) defines acceptable, and non-acceptable vent products and required Program and Payload verification requirements and methodologies.
- PIRN possibly impacts the CIR:
  - safety & hazardous reactions.
  - adhesion of vented gases (hexadecane and glycerol cause most of the problems)
  - reactions with ISS Vent System materials
  - wording of requirements
- SSP 57000-NA-0134B, Add Requirements for Payload Accumulators, imposes a new requirement on Racks to include accumulators to accommodate ITCS expansion and contraction due to Launch, and Landing environmental effects
- The CIR was designed for the US Lab, which makes provisions for expansion of fluids.
- CIR requires 15 accumulators (3 flt, 3 GIU, 3 EDU, 6 spares) at a significant cost.
- Cost, mass and volume impacts have been forwarded to the MRPO and ISSPO.



CIR to ISS Interfaces

- SSP 57000-NA-0135H, Payload Protrusion Requirements Change, defines a new protrusion envelope (19” in from the top and bottom of the rack and 3” in from the sides of the rack, and not to protrude more than 17” from the GSE Plane) for temporary protrusions
- The current CIR doors design violates this new requirement
- A Deviation Request For On-Orbit Temporary Protrusion Exceedance will be written and submitted to the ISSPO to envelope the balance of the temporary protrusions (e.g. rack doors)

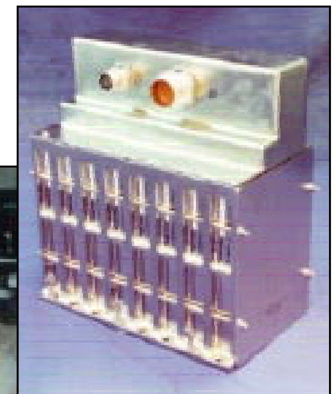


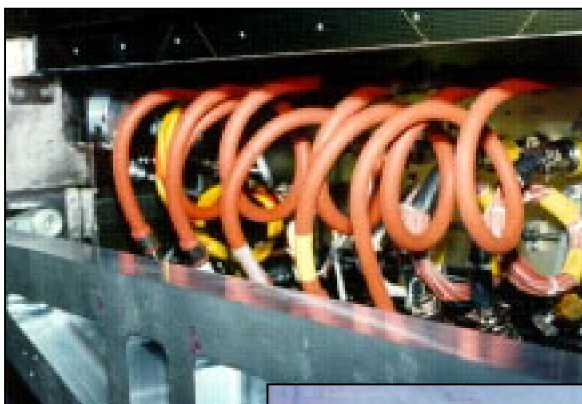


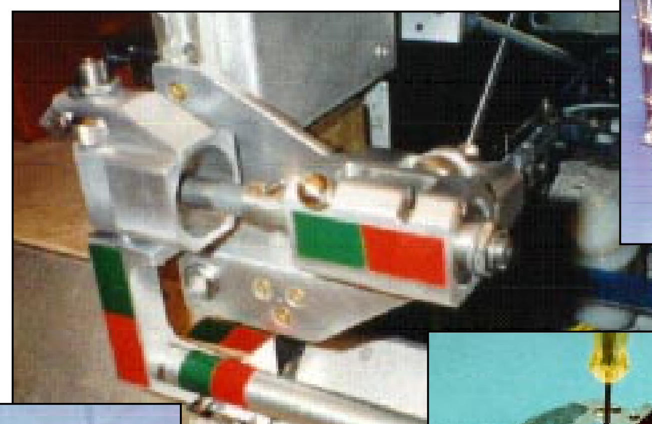
- SSP 57000-NA-151, Common Payload Pressure Drop, requires the CIR to meet a common pressure differential across the interface, therefore allowing it to meet all ISS Module requirements
- CIR primary ITCS loop will need to be divided into:
  - one loop for the HX
  - one loop connecting ARIS & the EPCU
- Cost, schedule, mass and volume impacts have been submitted to MRPO and the ISSPO

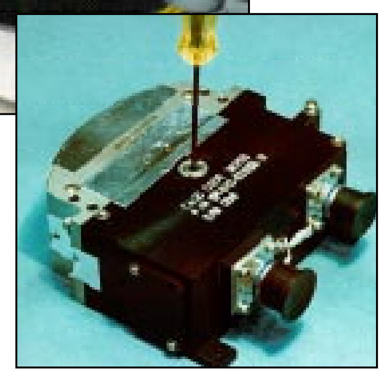
CIR to ISS Interfaces

- CIR - ARIS compatibility study must be conducted to identify issues and develop work plan to resolve issues.
- CIR - ARIS identified issues:
  - ARIS baselined on-orbit mass increase is limited to the launch mass limit requirement (804.2 kg), CIR control mass is 1000 kg
  - What are the ARIS impacts due to this increased mass
    - Actuators performance may be impacted
    - Integrated rack may consume more power



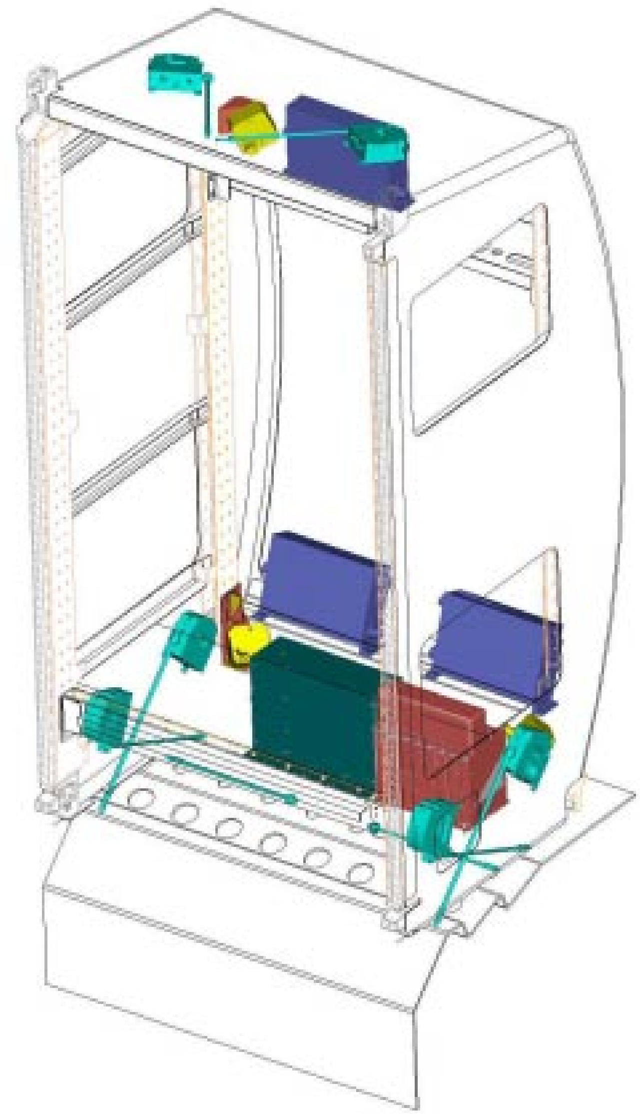






ARIS WORK PLAN

- Work Plan for ARIS
  - Perform Compatibility Assessment
  - Perform ISPR modifications to accommodate ARIS
  - Install ARIS Kit into ARIS Rack
  - Provide ARIS Stowed Items per the DIL
  - Provide ARIS Kit #5 per DIL
  - Develop & Provide two internal rack wiring harnesses
  - Perform simple trade studies for ARIS use (repackaging, performance)
  - Provide initial controller gains for each Payload
  - Provide ARIS/Payload integration support (answer questions, provide data)
  - Provide support for initial ARIS setup and operations
  - Provide controller gains updates for major reconfigurations of Payloads
  - Provide PDR & CDR Structural Analysis Reports
  - Provide ISPR Structural Integration/Coordination w/ SWG
  - PDR & CDR Review & Participation
  - Review Payload PDR & CDR Data Packages and provide comments



Requirements Compliance

John Haggard
Nora Bozzolo
Karen Weiland

Modeling of Combustion Basis Experiments

- **SRED requirement P9: After ISS and FCF assembly complete, FCF shall accommodate at least 80 percent of the microgravity combustion science experiments likely to be proposed for FCF. FCF compliance shall be shown by conceptual experiment layouts and analysis indicating that 80 percent of the combustion science Basis Experiments could be accommodated by FCF facility capabilities when augmented by PI hardware capabilities.**
- **Real experiments with Science Requirements Documents were substituted for the basis experiments in most cases to give a realistic look to this compliance effort. Project managers, project and facility scientists, and CIR design team participated.**
- **Hardware design presentation has shown compliance with individual SRED requirements. SRED requirements were shown in black, gray, or white boxes. In some cases, the SRD requirements were shown in red. The CIR capabilities were shown in various colored boxes on the graphs.**
- **Modeling results for each experiment will be presented separately from the hardware design presentation to show the level of compliance with SRED requirement P9.**

Experiment Modeling for CIR Experiments

- **Description of Effort:**
  - **selection of one representative "real" experiment for each SRED basis experiment, where possible**
  - **provide layouts of real experiments in CIR chamber to show feasibility of designs**
  - **review by PI hardware teams of key real experiment SRD requirements that fall on the PI hardware/CIR teams to meet.**
    - **determine if they are currently satisfied or are an interface challenge, or will never be met.**
    - **determine what hardware is used to meet the requirement and who is building it.**

Experiment Modeling for CIR Experiments

Representative Real Experiments	SRED Basis Experiments	SRED Basis Expt #	Current Accommodation
Droplet Combustion Experiment	Droplet Combustion Experiment	6	SL/CIR
Sooting & Radiative Effects in Droplet Comb.	Soot Measurements in Droplet Comb.	8	CIR
Flammability Diagrams of Combustible Material	Diffusive & Radiative Transport of Fires	4	CIR
Solid Infammability Boundary at Low Speed	Flammability Boundary of Solid Fuels	10	CIR
Transition From Ign. To Growth Under Ext. Rad.	Radiative Ignition and Flame Growth	11	CIR
Turbulent Gas Jet Diffusion Flames	Gas Jet Diffusion Flames	1	GAS Can
Microgravity Smoldering Combustion	Smoldering Combustion	5	GAS Can
Laminar Soot Processes	Laminar Soot Processes	7	SL/Spacehab
Structure of Flame Balls at Low Le #	Structure of Flame Balls at Low Le #	2	SL/Spacehab
Simplified Unsteady Burning of Contained Reactants	Unsteady Burning of Contained Reactants	9	-
Spread Across Liquids	Flame Spread Across Liquid Pools	3	Sounding Rocket

= grant expired

= not studied, personnel work conflict

SL = Spacelab

Experiment Modeling for CIR Experiments

Possible Grouping of Flight Experiments

SRED Basis Experiment	SRED Basis #	Real Flight Candidate Experiments	PI	Accommodation	Phase
Droplet Combustion Experiment	6	Droplet Combustion Experiment*	Williams	CIR	C
”	“	Bicomponent Droplet Combustion	Shaw	CIR	B
”	“	Dynamics of Droplet Extinction	Nayagam	CIR	A
Soot Measurements in Droplet Combustion	8	Sooting & Radiation Effects in Droplet Combustion*	Choi	CIR	A
Structure of Flame Balls at Low Le #	2	Water Mist Experiment	McKinnon - Commercial	CIR	N/A
Gas Jet Diffusion Flames	1	Turbulent Gas Jet Diffusion Flames*	Bahadori	GAS CAN	DONE
”	“	Modulated Turbulent Flames	Hermanson	CIR	A
”	“	Structure of Spherical Flames	Law	CIR	A
”	“	Lean Premixed Turbulent Flames	Cheng	CIR	A
”	“	Clean Efficient Diffusion Flames	Axelbaum	CIR	A
Diffusive & Radiative Transport in Fires	4	Flammability of Combustible Materials*	Fernandez - Pello	CIR	A
Flammability Boundaries of Solid Fuels	10	Flame Spread & Flammability	Tarifa - International	CIR	N/A
”	“	SIBAL*	Tien	CIR	B
”	“	Flame Tip Spread Instability	Wichman	CIR	A
”	“	Concurrent & Opposed Fl Spread	Ronney	CIR	A
Radiative Ignition & Flame Growth	11	Tiger 3-D*	Kashiwagi	CIR	B
Unsteady Burning of Contained Reactants	9	Cool Flames	Pearlman	CIR	A

▭ = multi-user CIR chamber insert hardware proposed   * = representative real experiment selection for basis experiment

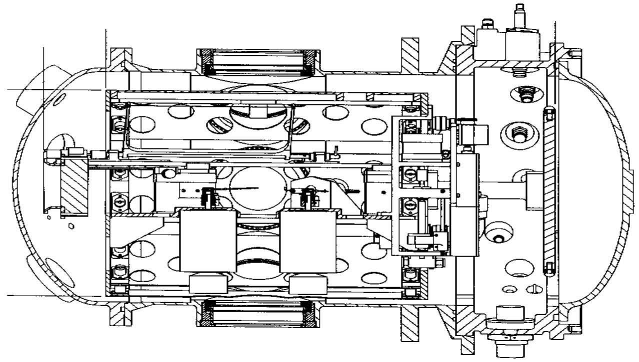
DROPLET COMBUSTION EXPERIMENT (C6)

Real Experiment Science Summary

- PI: Williams of UC San Diego
- PS: Nayagam-NCMR@ GRC

Experiment Summary

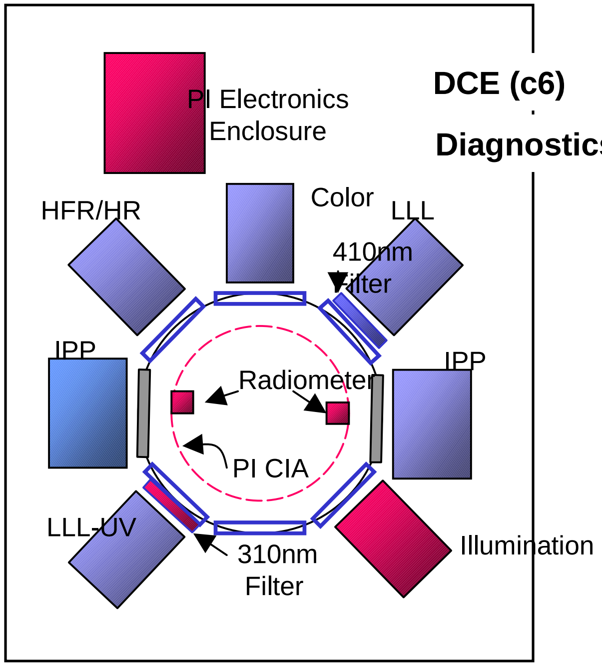
- single, liquid methanol/water droplets burn in quiescent O2/N2/He environments, freely deployed and with fiber support
- droplet size, flame location, flame radiation are measured
- burning rate constants, flame to droplet diameter ratios, key burning zone species concentrations, droplet extinction diameter, and broad band and water band radiation variations are found



CIR/DCE Chamber Insert Apparatus

Key CIR - Experiment Interface Requirements

- Chamber insert provides fuel, igniter assembly, droplet growth and deployment system and radiometers
- Atmosphere is .5 to 3 atm with O2/N2/He mixtures provided by the FOMA. Cleanup is between test points and before venting
- Diagnostics provided by CIR:
  - Flame images of OH and CH
  - Back lit droplet images at high frame rate and high resolution
  - Color images of droplet operations and ignition
- Acceleration environment .6 to 60 x 10^{-5} g/go provided by ARIS



DCE (c6)

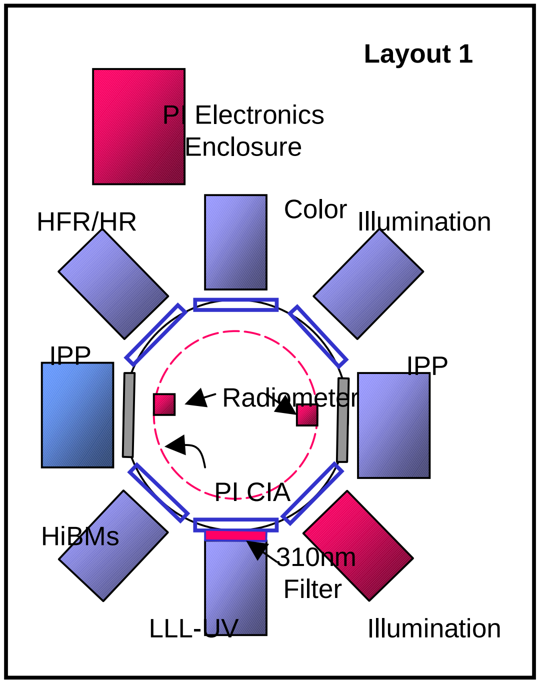
Diagnostics Layout in CIR

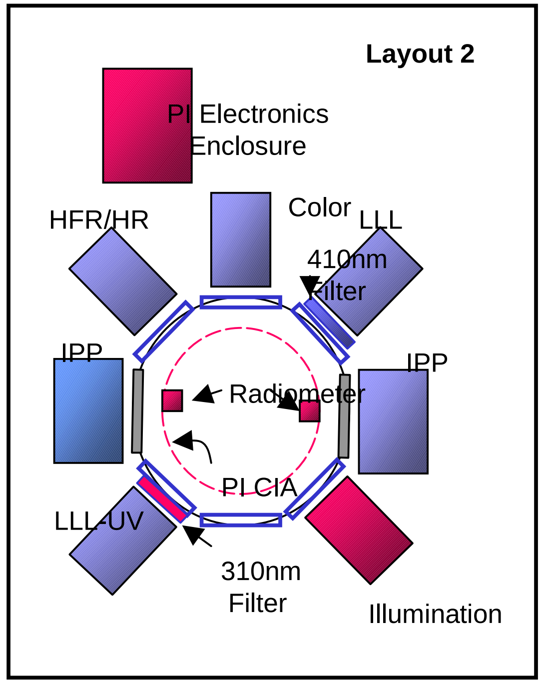
Summary of CIR/DCE II Compliance With DCE II SRD/Derived Requirements

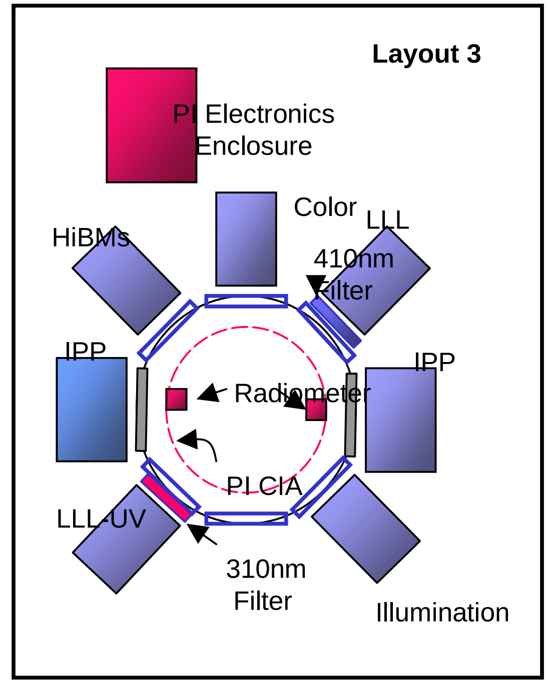
System	key requirement	CIR Hdwe	DCE Hdwe	Other Hdwe	Compliance
Test Chamber	Insert size: 62.7cm long x 36.9 cm dia	Chamber	insert		comply
	18 to 27C test environment	"		Water loop;Air cooling	"
	.5 to 3 atm initial pressure	"			"
Test Gas Conditions	O2 mole fraction 1% of desired	FOMA/ gas bottles	initial bottle gas mixtures		"
	water vapor <2%	FOMA filter			"
	O2 levels to 40 %	FOMA/ gas bottles	initial bottle gas mixtures		"
	He levels to 20%, rest N2	FOMA/ gas bottles	initial bottle gas mixtures		"
Acceleration Environment	need levels ~10-6 go			ARIS	"
	need measurement accuracy 10-6 go			SAMS FF	"
	need freq mesurement 0-125 Hz			SAMS FF	"
Minimum # Test Pts	80 pts in 4 months	CIR ops	DCE Ops	ISS Crew time/downlk	"
Droplet Imager	80 fps at 1cm fov, 20 um resolution	HFR/HR			"
	80 fps at 3 cm fov, 60 um resolution	HiBMs			"
	3 cm depth of field	either camera			"
Secondary Imager	30 fps	Color Cam			"
	4 cm fov	"			"
	4 cm dof	"			"
	std video resolution	"			"
CH & OH Imagers(2)	431 & 310 nm bandpass filters	LLL (2) & CH filter	OH filter		"
	30 fps	"			"
	90 um resolution	"			"
	4 cm fov	"			"
	4 cm dof	"			"
	colinear views for cameras	"	CIA arrangement		"
Data Requirements	all data time synched to .03 sec	IOP			"
Avionics	space for control & ops of CIA devices	Optics bench	avionics box		physical space need

Summary: DCE II interface requirements with CIR are capable of being met by the CIR design

DCE Optional Diagnostic Configurations







Start up Diagnostics Configuration

Dual cameras with different lenses keep droplet in field of view over a wide range of droplet velocities and only OH flame imaging

Preferred Diagnostics Configuration

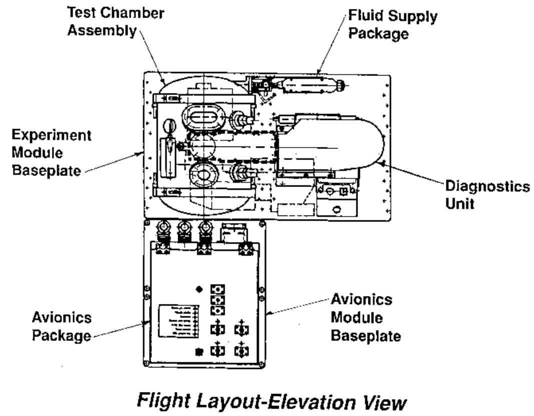
Single droplet imaging camera for low velocity droplet deployments and both OH and CH flame imaging

Alternate Diagnostics Configuration

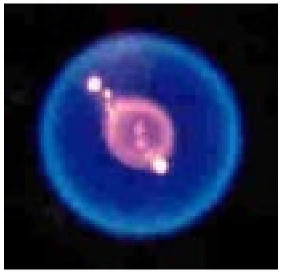
Single wide field of view droplet imaging camera for droplet deployments consistently in the high velocity range and both OH and CH flame imaging

Droplet Combustion Experiment 2

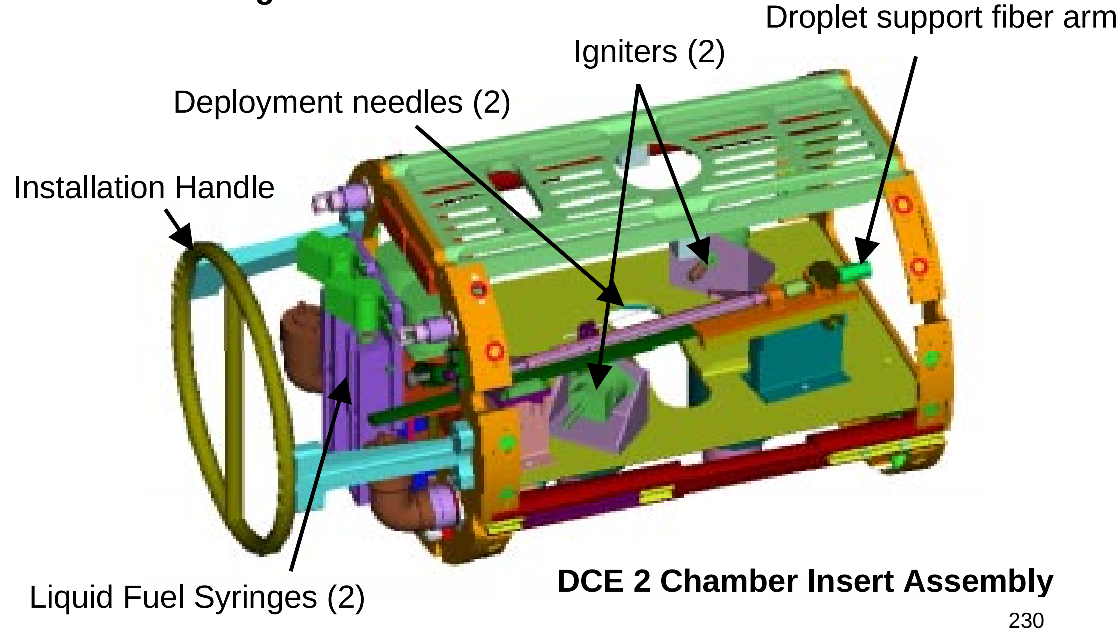
- PI: Prof. Forman A. Williams, University of California, San Diego
- Co-I: Prof. Frederick Dryer, Princeton
- Continuation of DCE which flew on the Microgravity Science Lab in 1997
- MSL configuration: 6 Middeck Locker Equivalent + stowage
- DCE
  - Heptane in O_2- He atmosphere
  - 35mm Film@80 fps & UV intensified (OH) on video
- DCE-2
  - Methanol/Water in O_2- He-N_2 atm.
  - Digital imaging & UV intensified (OH, CH) on video
- Held an Investigation Continuation Review on 2/24/99, Entering Phase C/D



DCE MSL Configuration



Droplet Image from MSL

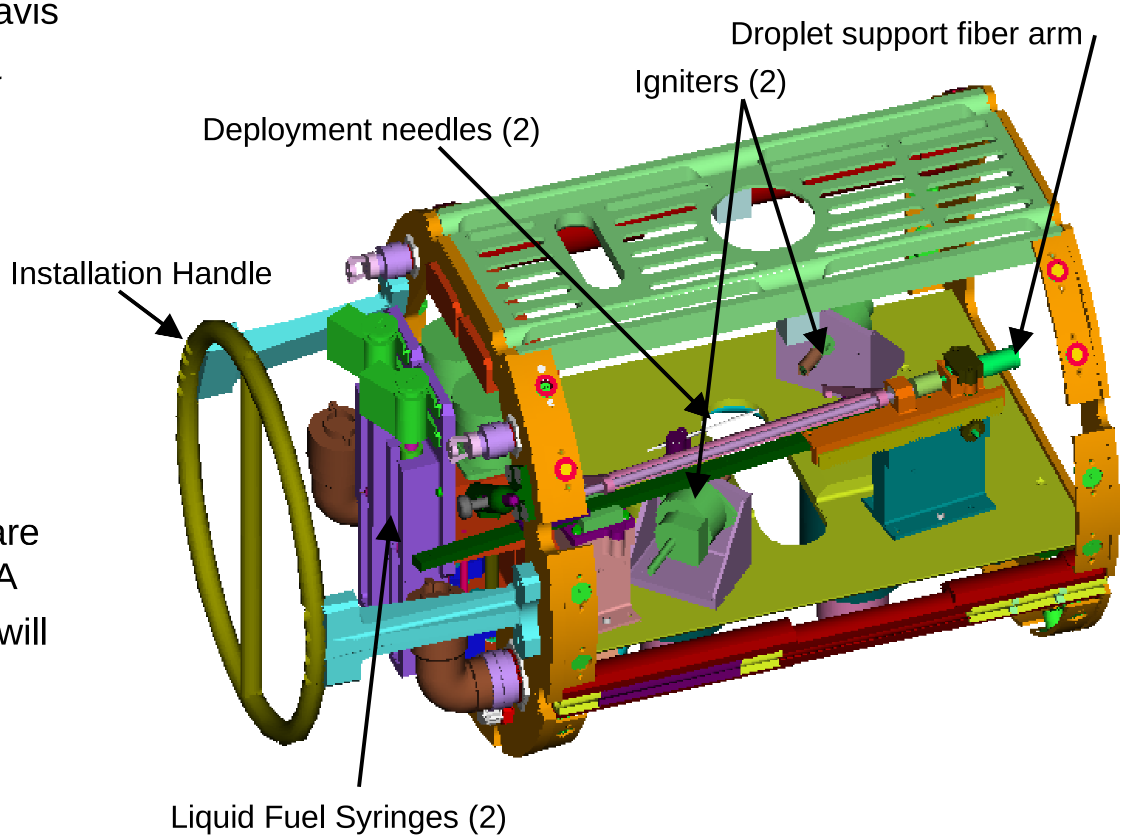


DCE 2 Chamber Insert Assembly

Bi-Component Droplet Combustion Experiment (BCDCE)

[Candidate Second Droplet Experiment For Multi-user Chamber Insert]

- PI: Prof. Benjamin Shaw, UC, Davis
- Heptane/Hexadecane mixtures & Propanol/Glycerol mixtures in an O_2-N_2 atmosphere.
- Diagnostics:
  - Imaging at 100fps
  - OH emissions
  - Droplet internal flow visualization
  - Color imaging
- Leverages off of the DCE hardware development. Will utilize DCE CIA
- Develop unique hardware which will be changed out on the CIA
- BCDCE had a Science Concept Review on 2/25/99, Entering Phase B



DCE 2 Chamber Insert Assembly

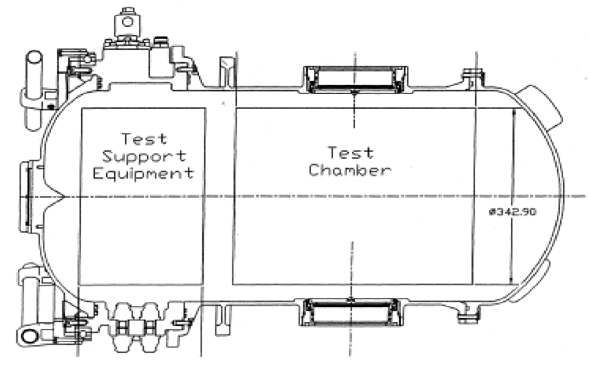
Sooting & Radiative Effects In Droplet Combustion (c8)

Real Experiment Science Summary

- PI: Choi, Un ILL@Chicago
- PS: Ferkul NCMR @ GRC

Experiment Summary

- single liquid heptane or ethanol droplets burn in quiescent O2/N2/He environments, freely deployed and with fiber support
- droplet size, flame location, soot concentration, temperature distributions, and soot morphology are measured
- burning rate constants, flame to droplet diameter ratios, soot properties and flame extinction will be obtained



CIR/SEDC Chamber Insert Apparatus

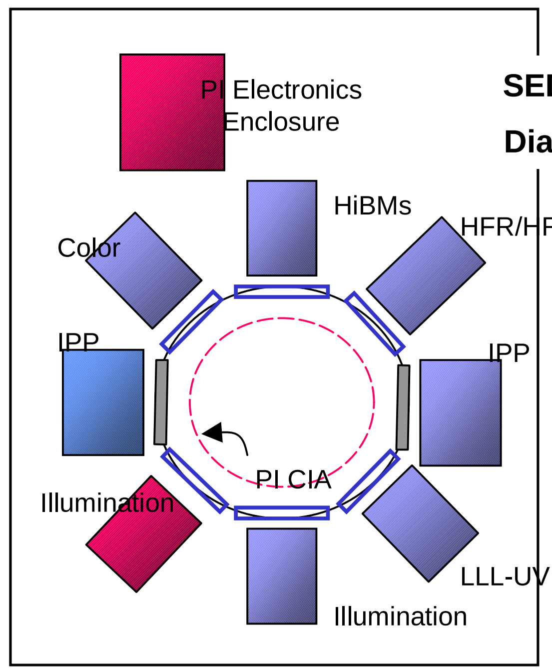
Key CIR - Experiment Interface Requirements

- Chamber insert provides fuel, igniter assembly, droplet growth and deployment system and soot sampling
- Atmosphere is .25 to 2 atm with O2/N2/He mixtures provided by the FOMA. O2 concentration range from 15 to 50%. Cleanup is between test points and before venting

Diagnostics provided by CIR:

- Back lit droplet images at high frame rate and high resolution
- Soot Volume Fraction and 2-wavelength pyrometry images
- Color images of droplet operations and ignition
- OH flame emission images

- Acceleration environment 10^{-6} g/go provided by ARIS



SEDC (c8)

Diagnostics Layout in CIR

Summary of CIR/SEDC Compliance With SEDC SRD/Derived Requirements

System	key requirement	CIR Hdwe	SEDC Hdwe	Other Hdwe	Compliance
Test Chamber	Insert size: 64 cm long x 34.5 cm dia	Chamber	insert		comply
	18 to 27 oC test environment	Chamber		Water loop;Air cooling	"
	.5 to 2 atm initial pressure	Chamber			"
Test Gas Conditions	O2 mole fraction 1% of desired	FOMA/ gas bottles	initial bottle gas mixtures		"
	O2 levels to 50 %	FOMA/ gas bottles	initial bottle gas mixtures		"
	He levels to 40%, rest N2	FOMA/ gas bottles	initial bottle gas mixtures		"
Acceleration Environment	need levels ~10-5 go			ARIS	"
	need measurement accuracy 10-6 go			SAMS FF	"
Droplet Imager	100 fps	HFR/HR			"
	50 um resolution	"			"
Color imager of flame	100 fps	Color Cam			"
	5 cm fov	"			"
	50 um resolution	"			"
OH flame imager	310± 10 um acceptance	LLL	OH filter		"
	30 fps	"			"
	90 um resolution	"			"
	6 cm fov	"			"
	4 cm dof	"			"
2 wavelength pyrometry & soot volume fraction camera	700 & 800 nm/ 675 nm	HiBMs w/ liquid filter			"
	100 fps	"			frame rate limited by filter cycling time
	resolution 50 um	"			Resolution compromised by binning
	5 cm fov	"			comply
	range: 1000 to 2500 K, acc 50 K	"			"
	> 250 gray scales	"			"

Summary: SEDC interface requirements with CIR, with some negotiation/invention on 2 cameras framing rates, are capable of being met by the CIR design

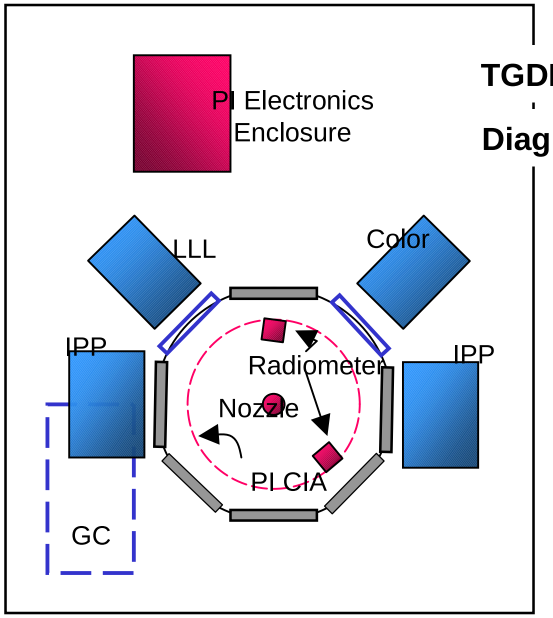
Turbulent Gas Jet Diffusion Flames (c1)

Real Experiment Science Summary

- PI: Bahadori
- PS: Stocker, GRC

Experiment Summary

- propane gas jet diffusion flames burn that are physically disturbed near the base of the flame
- flame size and flame location in response to imposed disturbances are measured

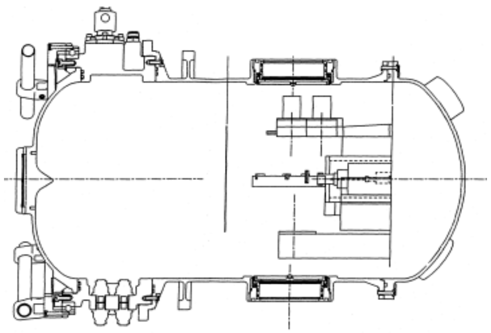


TGDF (c1)

Diagnostics Layout in CIR

Key CIR - Experiment Interface Requirements

- Chamber insert provides fuel, igniter assembly, temperature point measurement devices and flame disturbance mechanism
- Atmosphere is 1 atm with O2/N2 mixtures provided by the FOMA. O2 concentration 22%.
- Diagnostics provided by CIR:
  - Two orthogonal views of the flame. One color.
  - Chemical composition of the burned gas samples
- Acceleration environment range 10^{-3} to 10^{-5} g/go provided by ARIS



CIR/TGDF Chamber Insert Apparatus

Summary of CIR/TGDF Compliance With TGDF SRD/Derived Requirements

System	key requirement	CIR Hdwe	TGDF Hdwe	Other Hdwe	Compliance
Test Chamber	Insert size: 28.7cm long x 34.2 cm dia	Chamber	insert		comply
	interior wall emissivity >.9 over visable	Test chamber			"
	initial press 1 atm, final to 2.5 atm @ 48 l.	"			"
Test Gas Conditions	O2 mole fract acc .3% of desired	FOMA gas bottles	intial bottle gas mixtures		"
	O2 mole fraction 22%	FOMA gas bottles	intial bottle gas mixtures		"
	N2 mole fraction 78%	FOMAgas bottles	intial bottle gas mixtures		"
	post burn analysis: CO,CO2,O2 propane	Gas Chromo.			"
	to 5%; NO,NO2, N2 to 10%	Gas Chromo.			"
gaseous fuel flow	flow rate of 1.86 + .04 cc/s				"
Acceleration Environment	need levels ~10-4 go			ARIS	"
	need freq mesurement 0-15 Hz			SAMS FF	"
Minimum # Test Pts	32 pts	CIR ops	TGDF Ops	ISS Crew time/downlk	"
Test Duration Estimate	500 sec	Test chamber			"
flame disturbance imaging	30 fps	Color Cam			"
	18 x 8 cm fov	"			"
	5 cm dof	"			"
	resolution: 500 - 1000 um	"			"
low light level imaging	30 fps	HiBMS			"
	18 x 8 cm fov	"			"
	5 cm dof	"			"
	resolution: 500 - 1000 um	"			"
	orthogonal view to color camera	"	CIA arrangement		"

Summary: TGDF interface requirements with CIR are capable of being met by the CIR design

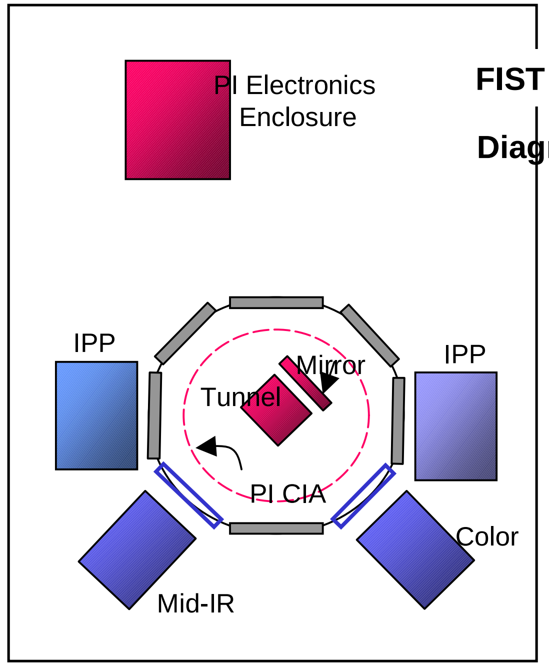
Flammability Diagrams of Combustible Material (c4)

Real Experiment Science Summary

- PI Fernandez-Pello, UC Berkeley
- PS Ross GRC

Experiment Summary:

- study ignition and flame spread of solid samples with external radiant heat flux and opposed chamber gas flow
- ignition time, flame spread, flame size measurements as a function of external radiant flux, flow velocity and oxygen concentration

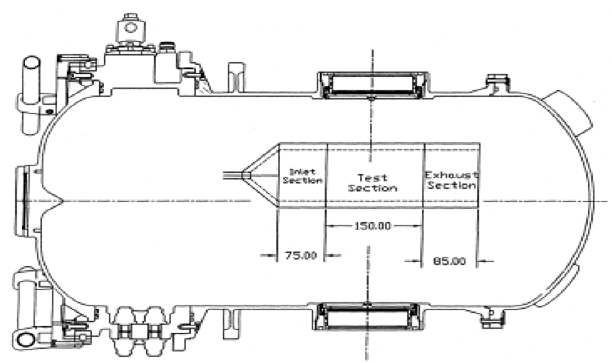


FIST (c4)

Diagnostics Layout in CIR

Key CIR - Experiment Interface Requirements

- Chamber insert provides fuel, igniter assembly, radiant heater and flow duct
- Operating pressure is 1 atm with O2/N2 mixtures provided by the FOMA. O2 concentration range from 18 to 25%. Recirculation mechanism is PI provided
- Diagnostics provided by CIR:
  - Color images of flame spread
  - Infrared Image of fuel surface
- Acceleration environment $5x10^{-5}$ g/go provided by ARIS



CIR/FIST Chamber Insert Apparatus

Summary of CIR/FIST Compliance With FIST SRD/Derived Requirements

System	key requirement	CIR Hdwe	FIST Hdwe	Other Hdwe	Compliance
Test Chamber	Insert size: 39.1 cm long x 12.5 cm dia initial press 1 atm ± .2 atm	Chamber Test chamber	insert		comply "
Test Gas Conditions	O2 mole fract acc .5% O2 mole fraction range: 18- 25%, rest N2 < 10% relative humidity	FOMA gas bottles FOMA gas bottles FOMA filters	intial bottle gas mixtures intial bottle gas mixtures		" " "
Flow duct conditions	15 cm long x 10cm x 10cm 30 to 115 std liters/min flow @ 1± .2 atm	CIR to 90 SLM	Recirculation until ignition		" CIR FOMA supply/vent flow through rate 20 SLM FOMA max if vent filter required
Radiant sample heating	40 - 200 watts radiant power to surface gas cool needs from burning & rad heating				elect. to delivered radiant power conversion taxes CIR available PI power excess vent/chamber temp
Acceleration Environment	need levels 5 x 10-5 g/go need freq mesurement 0-10 Hz			ARIS SAMS FF	comply "
Minimum # Test Pts Test duration	32 pts ~ 10 min	CIR ops	DCE Ops	Crew time/downlk	" CIR FOMA supply flow time
Color camera	30 fps 20 x 5 cm fov 5 cm dof standard video	Color Cam " " "			comply " " "
IR Imaging camera	30 fps 20 x 5 cm fov 5 cm dof resolution: 1000 um orthogonal view to color camera	Mid-IR pkge " " " "	CIA arrangement		" " " " "

Summary: FIST interface requirements with CIR, with some negotiation/invention on FOMA system blowdown specs/ test crossection minimums & minimal radiant heater needs , are capable of being met by the CIR design

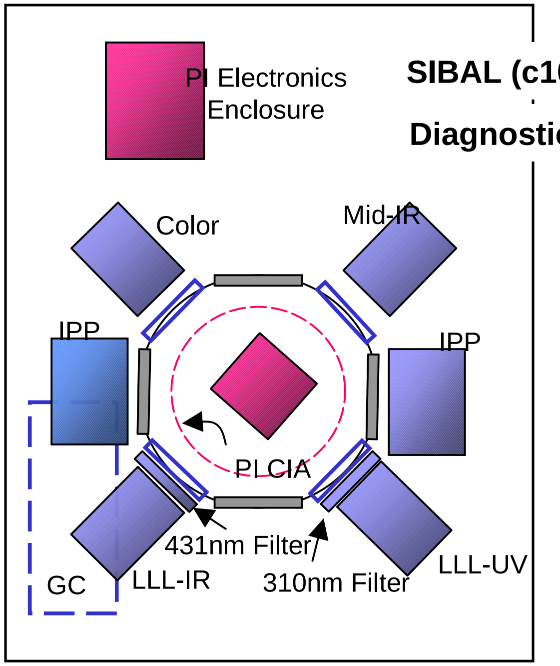
Solid Inflammability Boundary At Low Speed (c10)

Real Experiment Science Summary

- PI: T'ien, Case-Western
- PS Ferkul, NCMR @ GRC

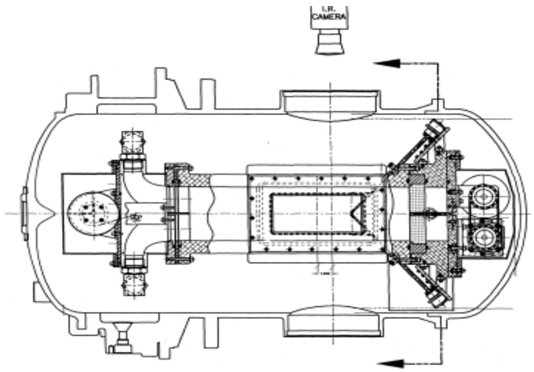
Experiment Summary

- Verify predicted extinction boundaries in concurrent flame spread across a thin solid fuel.
- flame spread, flame size and shape, temperature, heat release measurements are made at a series of gas flow velocities and oxygen concentrations.



Key CIR - Experiment Interface Requirements

- Chamber insert provides fuel, igniter assembly, temperature point and radiometric measurement devices
- Operating pressure is 1 atm with O2/N2 mixtures provided by the FOMA. O2 concentration between 10% and 30%.
- Diagnostics provided by CIR:
  - One color, one CH and one OH view of the flame.
  - Infrared imaging of CO2, H2O and soot fields
  - Chemical composition of the burned gas samples
- Oxidizer flow from 0 to 15cm/s can be partially provided by FOMA
- Acceleration environment range 10^{-4} g/go provided by ARIS



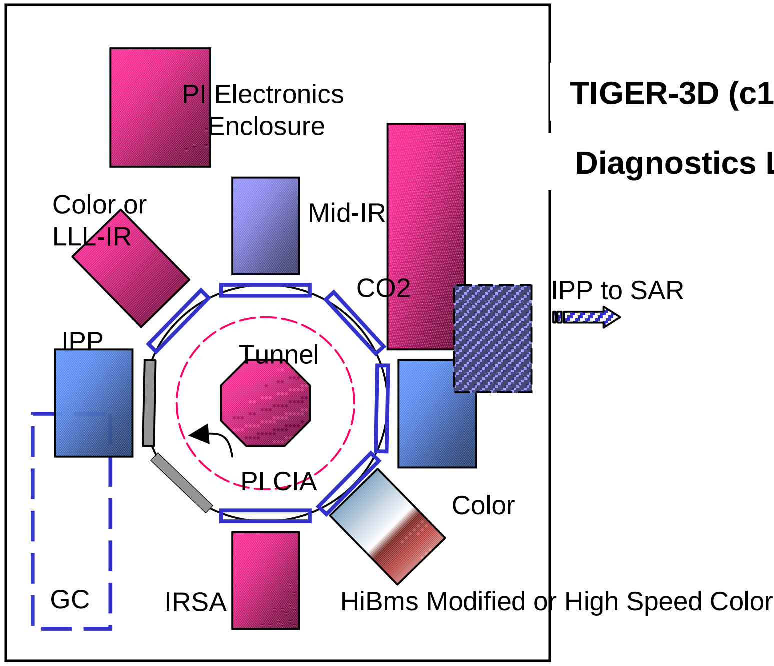
CIR/SIBAL Chamber Insert Apparatus

Summary of CIR/SIBAL Compliance With SIBAL SRD/Derived Requirements

System	key requirement	CIR Hdwe	SIBAL Hdwe	Other Hdwe	Compliance
Test Chamber	Insert size: 78.3 cm long x 38.1 cm dia initial press 1 atm ± .05 atm	Chamber Test chamber	insert		CIR fan removal/insert mod comply
Test Gas Conditions	O2 mole fract acc 1% O2 mole fraction range: 10- 30%, rest N2 < 50% relative humidity	FOMA gas bottles FOMA gas bottles FOMA filters	intial bottle gas mixtures intial bottle gas mixtures		" " "
Flow duct conditions	30 cm long x 11cm x 11cm 0 to 25 std liters/min flow @ 1 atm 25 to 95 std liters/min flow @ 1 atm	CIR to 90 SLM "	Chamber recirculation to ignition		" 20 SLM FOMA max if vent filter reqd CIR FOMA supply/vent flow rate
Acceleration Environment	need levels 5 x 10-5 g/go need freq mesurement 0-10 Hz			ARIS SAMS FF	comply "
Minimum # Test Pts	21 pts	CIR ops	SIBAL Ops	Crew time/downlk	"
Test duration	>20 minutes				CIR FOMA supply flow time
Flame imaging	>10 fps 10 x 10 cm fov resolution: 200 um	Color Camera " "			comply " "
CH flame zone edge image	wavelength 431 nm (CH) >10 fps 10 x 10 cm fov resolution: 200 um	HiBMS " " "	CH filter		" " " "
IR flame zone & fuel surface measurement camera	Flame wavelengths:4.3(CO2),1.87(H2O),1.6,&3.8um >1 fps 10 x 10 cm fov resolution: 200 um	Mid-IR pkge " " "	multielement filter wheel & insert mirror assembly		" " " "
OH flame imager	wavelength 310 nm (OH) >1 fps 10 x 10 cm fov resolution: 200 um	UV intensified pkge " " "	OH filter		comply " " "

Summary: SIBAL interface requirements with CIR, with some negotiation/invention on FOMA system blowdown specs/ test crossection minimums & chamber fit adjustments , are capable of being met by the CIR design

Transition From Ignition to Growth Under External Radiation (c11)



TIGER-3D (c11)

Diagnostics Layout in CIR

Real Experiment Science Summary

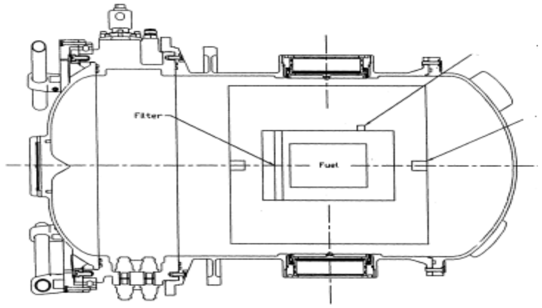
- PI: Kashiwagi, NIST
- PS: Olson, GRC

Experiment Summary

- Study 2 and 3 dimensional radiant ignition and transition to flame spread of solid cellulose and PMMA samples under low speed flows.
- Ignition time, shape and flame size, flame color, spectral emissions and temperature measurements are made.

Key CIR - Experiment Interface Requirements

- Chamber insert provides fuel, temperature point measurement devices and fans for oxidizer flow. CO2 ignition system external to chamber.
- Operating pressure is 1 atm with O2/N2 mixtures provided by the FOMA. O2 concentration 21%.
- Diagnostics provided by PI: High speed color sample edge view and IRSA system
- Diagnostics provided by CIR:
  - Two color images: one edge view and one surface view.
  - IR images of fuel surface temperature
  - Chemical composition of the burned gas samples
- Acceleration environment range 10^{-4} g/go provided by ARIS



CIR/TIGER-3D Chamber Insert Apparatus

Summary of CIR/TIGER 3-D Compliance With TIGER 3-D SRD/Derived Requirements

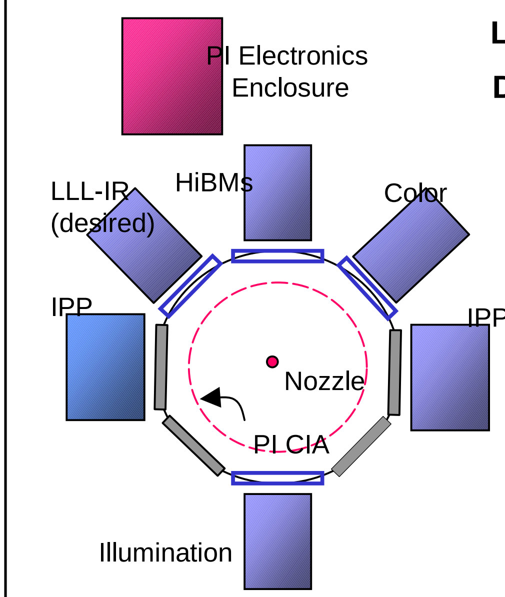
System	key requirement	CIR Hdwe	TIGER 3D Hdwe	Other Hdwe	Compliance
Test Chamber	Insert size: 40 cm long x 40 cm dia initial press 1 atm ± .05 atm	Chamber Test chamber	insert		comply "
Test Gas Conditions	O2 mole fract acc .3% O2 mole fraction range:20.9%,rest N2	FOMA gas bottles FOMA gas bottles	intial bottle gas mixtures intial bottle gas mixtures		" "
Flow duct conditions	24 cm long x 16cm x 12cm 6 to 234 std liters/min flow @ 1 atm	CIR to 90 SLM -supply limit	Recirculation fan in chamber O2 sensor		" 20 SLM FOMA max if vent filter required- vent limit CIR FOMA supply/vent+recirculation flow rate O2sensor feedback loop to FOMA supply/vent sys + active pressure control during dynamic gas supply
Acceleration Environment	need levels 10-4 g/go need freq mesurement 0-10 Hz			ARIS SAMS FF	comply "
Minimum # Test Pts Test duration	30 pts ~ 20 minutes	CIR ops	Tiger 3D ops	Crewtime/downlk	" CIR FOMA supply flow time
Laser Ignition in 2-d & 3 -d tests	TBD Watts/cm2		CO2 laser, turning mirrors, focusing optics & windows		safety compatibility with CIR system laser power requirements
Color camera surface view	30 fps 10 x 10 cm fov resolution: 500 um	Color Camera " "			comply " "
Color camera edge view	30 fps 4x 3 cm fov resolution: 250 um	Color Camera " "			" " "
Color camera (edge view)	200-500 fps 4x 3 cm fov resolution: 250 um		high speed color camera		large amounts of data storage & transmission " "
IR Imaging camera for surface temperature	60 fps 8 x10 cm fov resolution: 500 um temperature range: 400 -1100 ± 30K	Mid-IR pkge & windows " "			" " " "

Summary: TIGER -3D requirements as currently defined in the PI's SRD will be difficult to meet with CIR/FCF

Laminar Soot Processes Experiment (C7)

LSP (c7)

Diagnostics Layout in CIR



Real Experiment Science Summary

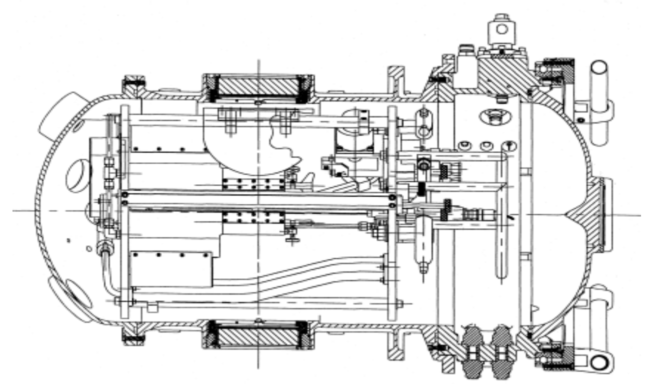
- PI: Faeth, U of Mich
- PS: Urban, GRC

Experiment Summary

- A round laminar gas jet diffusion flame of ethylene or propane burns in an initially quiescent environment
- Soot volume fraction, soot temperature, flame radiation are measured. Soot samples are taken
- Flame shape and size, soot morphology, and smoke heights are found

Key CIR - Experiment Interface Requirements

- Chamber insert provides fuel, igniter assembly, temperature point measurement and flame radiation devices and soot sampler.
- Operating pressures are 0.5 and 1 atm with O2/N2 mixtures provided by the FOMA. O2 concentration 21%.
- Diagnostics provided by CIR:
  - Two orthogonal views of the flame: One color, another LLL is available for a second desired view.
  - Light absorption and 2-wavelength pyrometry images for soot volume fraction and soot temperature measurements
- Acceleration environment 10^{-4} g/go provided by ARIS



CIR/LSP Chamber Insert Apparatus

Summary of CIR/LSP Compliance With LSP SRD/Derived Requirements

System	key requirement	CIR Hdwe	LSP Hdwe	Other Hdwe	Compliance
Test Chamber	Insert size: 66.6 cm long x 39.6 cm dia interior wall emissivity >.8 over visible initial press .5&1 atm,final< 5%rise	Chamber Test chamber "	insert		comply " "
Test Gas Conditions	O2 mole fract acc 1% of desired O2 mole fraction 21% N2 mole fraction 78% max of 10% O2 consumed in test	FOMA gas bottles FOMA gas bottles FOMAgas bottles Gas Chromo.	intial bottle gas mixtures intial bottle gas mixtures intial bottle gas mixtures		" " " "
gaseous fuel flow	flow rate .7 - 1.93 mg/s	FOMA supply	inert nozzle		"
Soot sampling probes	TEM grids at 4 locations transit time <50 msec residence time 200-500 sec	air for insert solenoids	grids, probes solenoids "		chamber internal tap for air comply "
Acceleration Environment	need levels <10-3 g/ go need freq measurement 0-15 Hz			ARIS SAMS FF	" "
Minimum # Test Pts Test Duration Estimate	14 pts < 250 sec	CIR ops Test chamber	LSP Ops	ISS Crew time/downlk	" "
Color camera for flame imaging	1 fps 8 x 6 cm fov 2.5 cm dof resolution 750 um	Color Cam " " "			" " " "
soot volume fraction camera	wavelength: 600-900 um (675 um) resolution: 1000 nm 3 cm fov full field	HiBMs w/ filter " "			" " "
2 wavelength pyrometry	632.8 & 900 nm resolution 500um 3 cm fov full field range: 800 to 1100 K	HiBMs w/ liquid filter " " "			" " " "

Summary: LSP interface requirements with CIR are capable of being met by the CIR design

Structure of Flame Balls at Low Lewis #s (c2)

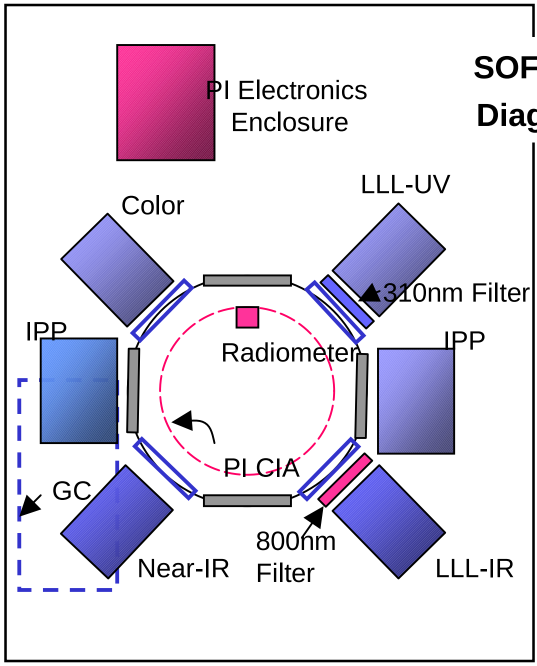
Real Experiment Science Summary

- PI: Ronney, USC
- PS: Weiland, GRC

Experiment Summary

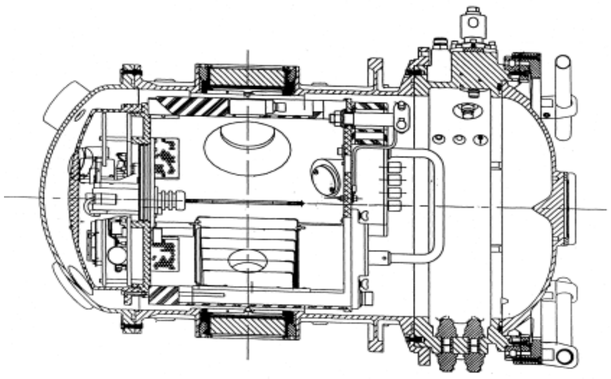
- Study flame balls that exist in a spark ignited, premixed quiescent environment
- Flame shape, size and structure, length of burn time, temperature, flame radiation and amount of fuel and O2 consumed are found

SOFBALL (c2) Diagnostics Layout in CIR



Key CIR - Experiment Interface Requirements

- Chamber insert provides ignition mechanism, radiometric detection and point temperature measurements
- Fuel/oxidizer/diluent mixtures provided by FOMA
- Operating pressure is 1 or 3 atm.
- Diagnostics provided by CIR:
  - Three flame views: One provides long pass wavelength detection orthogonal to OH imaging. Third vie is color.
  - Species composition via GC.
- Acceleration environment range 10^{-5} to 0.05 g/go is provided by ARIS



CIR/SOFBALL Chamber Insert Apparatus

Summary of CIR/SOFBALL Compliance With SOFBALL SRD/Derived Requirements

System	key requirement	CIR Hdwe	Sofball Hdwe	Other Hdwe	Compliance
Test Chamber	Insert size: 62.2 cm long x 39.6 cm dia interior wall emissivity >.9 over visible initial press 1-3 atm, accuracy 3% of reading	Chamber Test chamber "	insert		comply " "
Test Gas Conditions	mole fract acc 2% of desired for each component O2 mole fraction range 8-20%, H2 3.35 - 7.67% other gases are CO2, N2, SF6 toxic/corrosive gas (HF, SO2) cleanup required	FOMA gas bottles FOMA gas bottles FOMA gas bottles FOMA filters	intial bottle gas mixtures intial bottle gas mixtures intial bottle gas mixtures		" " " "
Post burn analysis	looking for: H2,O2,CO2,H2O, SF6, N2 & CO to 2%	Gas Chromo. Gas Chromo.			" "
Acceleration Environment	need levels 10-4 g/go needs long (~500 sec) micro-g			ARIS ISS planning	" "
Test Chamber	interior wall emmissitivity >.9 over visable initial press 1-3 atm, accuracy 3% of reading	Test chamber "			" "
Minimum # Test Pts	30 pts	CIR ops	Sofball Ops	ISS Crew time/downlk	"
Test Duration Estimate	100-500 sec	Test chamber			"
Color camera	30 fps 30 x 22.5 fov 30 cm dof 2200 um resolution	Color Cam " "			" " CIR lens dof limit comply
LLL cameras -IR(2)	30 fps 30 x 22.5 fov 30 cm dof 800 nm long pass filter for 1 Cam orthogonal view to color camera	near IR LLL pkge " " " "	filter CIA arrangement		" " CIR lens dof limit comply "
LL camera -UV	30 fps 30 x 22.5 fov 30 cm dof wavelength: 310 nm	LLL-UV pkge " " "			" " CIR lens dof limit comply

Summary: SofBall interface requirements with CIR, with some needed development in moving cameras away from the window to gain camera depth of field, are capable of being met by the CIR design

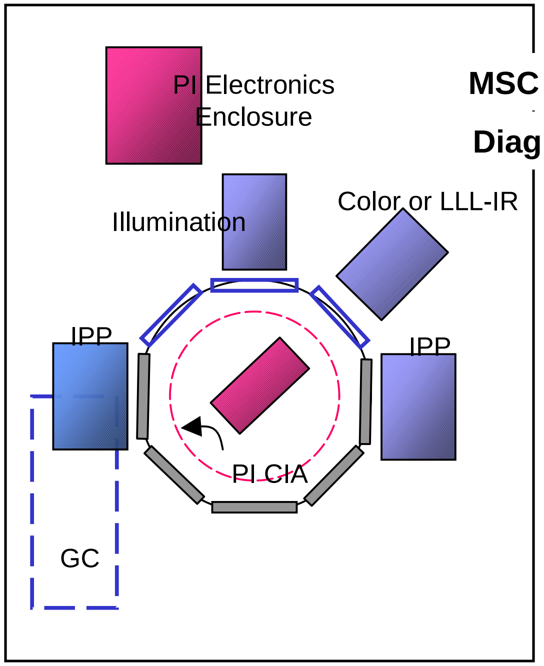
Microgravity Smoldering Combustion Experiment (c5)

Real Experiment Science Summary

- PI: Fernandez-Pello, UC
- PS: Urban, GRC

Experiment Summary

- A porous combustible sample of polyurethane foam is heated to ignition by an igniter wire under opposed or concurrent flow, or in a quiescent environment
- Smoldering combustion front is monitored and temperature measurements are taken

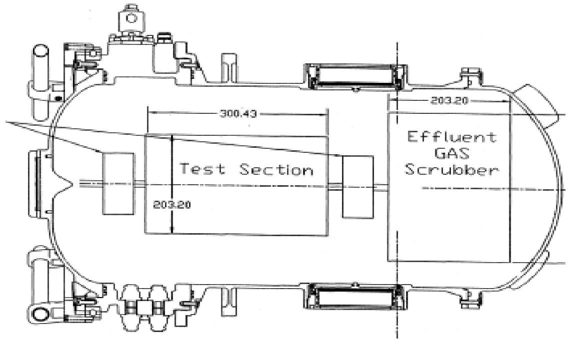


MSC (c5)

Diagnostics Layout in CIR

Key CIR - Experiment Interface Requirements

- Chamber insert provides fuel, sample holder, igniter assembly, and temperature point measurement.
- Operating pressure 1 atm with O_2/N_2 mixtures ranging from 21 to 40% and oxidizer flow from 0.3 to 7 mm/s provided by the FOMA.
- Diagnostics provided by CIR:
  - Illumination of the smoldering region
  - One color image of combustion event throughout it duration.
  - Composition of O_2, CO, CO_2, N_2 and CH_4 via GC
- Acceleration environment $<10^{-3}$ g/go provided by ARIS



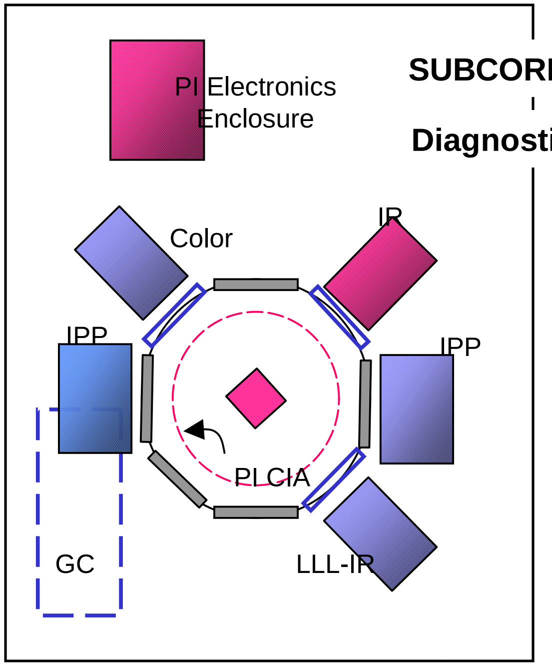
CIR/MSC Chamber Insert Apparatus

Summary of CIR/MSC Compliance With MSC SRD/Derived Requirements

System	key requirement	CIR Hdwe	MSC Hdwe	Other Hdwe	Compliance
Test Chamber	Insert size: 59.5 cm long x 38.1 cm dia 1atm + 10%initial pressure	Chamber Chamber	insert		comply "
Test Gas Conditions	O2 mole fraction .5% of desired relative humidity <10% O2 levels to 21-40 % He levels to 40%, rest N2	FOMA/ gas bottles FOMA filter FOMA/ gas bottles FOMA/ gas bottles	initial bottle gas mixtures initial bottle gas mixtures initial bottle gas mixtures		" " " "
Post burn analysis	looking for: CH4,CO,CO2,O2,H2O, & N2	Gas Chromo.			comply
Ultrasound imaging	5 locations in sample every 10 sec		ultrasound system		acoustic signature limits for rack
Oxidizer flow	.2 - 4.7 std liters/min	FOMA			flows below CIR FOMA limit
Acceleration Environment	need levels ~10-3 g/go			ARIS	comply
# Test Pts Test Duration	12 pts 50-120 minutes	CIR ops	MSC	ISS Crew time/downlk	" "
Color camera	.2 fps 12 x 10 cm fov resolution:~5000 um	Color Camera " "			" " "

Summary: MSC interface requirements with CIR are capable of being met by the CIR design

Simplified Unsteady Burning of Contained Reactants (c9)



Real Experiment Science Summary

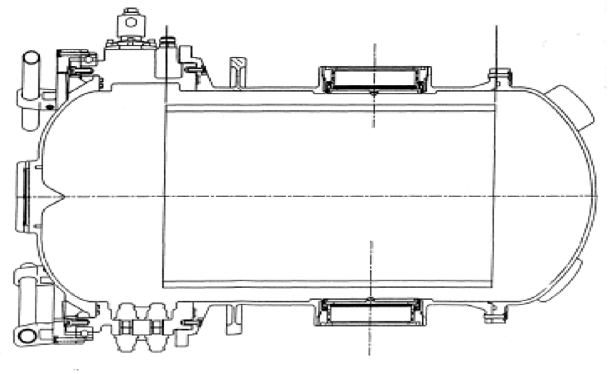
- PI: Fendell, TRW
- PS: Gokoglu, GRC

Experiment Summary

- A planar diffusion flame is formed at the surface between gaseous fuel (hydrogen) and oxidizer
- The flame position is measured by flame images and temperature

Key CIR - Experiment Interface Requirements

- Chamber insert provides fuel, separator, igniters assembly, and temperature point measurement. The insert must provide additional containment to support 9.5 atm of max pressure.
- Operating pressures are in the range of 0.5 to 1 atm with O2 diluted with He, Ne, Ar or Xe provided by the FOMA.
- Diagnostics provided by CIR:
  - Two views: one color and one B/W image of combustion event to also capture separator translation.
  - Composition of O2, H2 and inert gases via GC
- Acceleration environment <10^{-5} g/go provided by ARIS



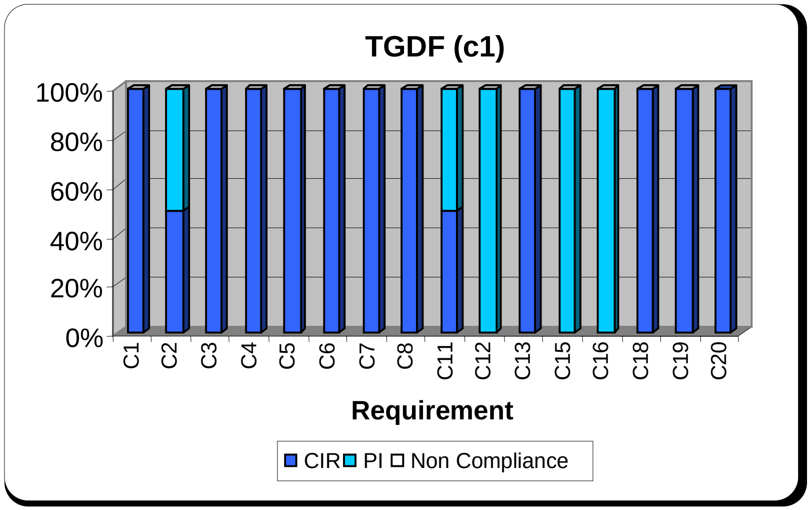
CIR/SUBCORE Chamber Insert Apparatus

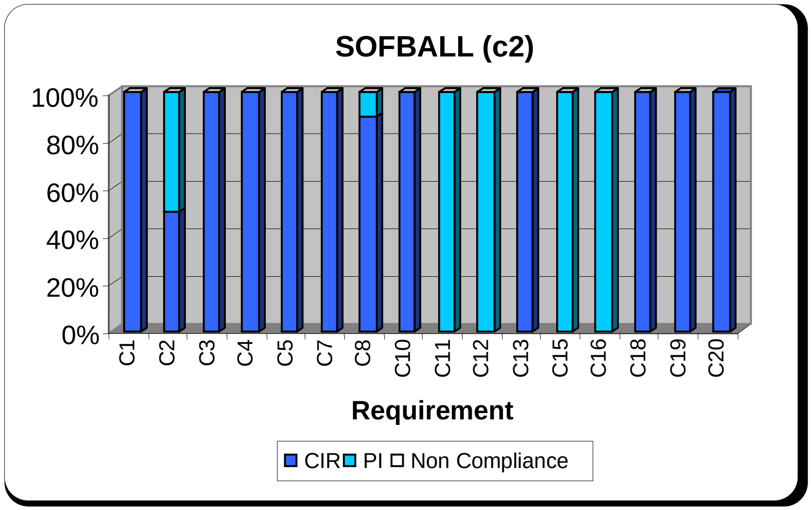
Summary of CIR/SUBCORE Compliance With SUBCORE SRD/Derived Requirements

System	key requirement	CIR Hdwe	Subcore Hdwe	Other Hdwe	Compliance
Test Chamber	Insert size: 50.8 cm long x 35.5 cm dia .5 - 1atm + 3%initial pressure	Chamber Chamber	insert		comply "
Test Gas Conditions	O2 mole fraction .5% of desired relative humidity <10% O2 with He,Ne, Ar, Xe dilution hydrogen is fuel	FOMA/ gas bottles FOMA filter FOMA/ gas bottles FOMA/fuel bottle	intial bottle gas mixtures intial bottle gas mixtures		" " " system transport & handling
Post burn analysis	looking for: H2,O2,H2O, & inerts	Gas Chromo.			comply
Acceleration Environment	need levels ~10-5 g/go			ARIS	"
# Test Pts	20 pts	CIR ops	Subcore Ops	ISS Crew time/downlk	"
Color camera	30fps 7.5 x 2.5 cm fov resolution:1000 um	Color Camera " "			" " "
LLL-IR image camera	30fps 2.5 x 7.5 cm fov resolution:1000 um	Color Camera " "			" " "

Summary: Subcore interface requirements with CIR are capable of being met by the CIR design

Science Requirements Compliance



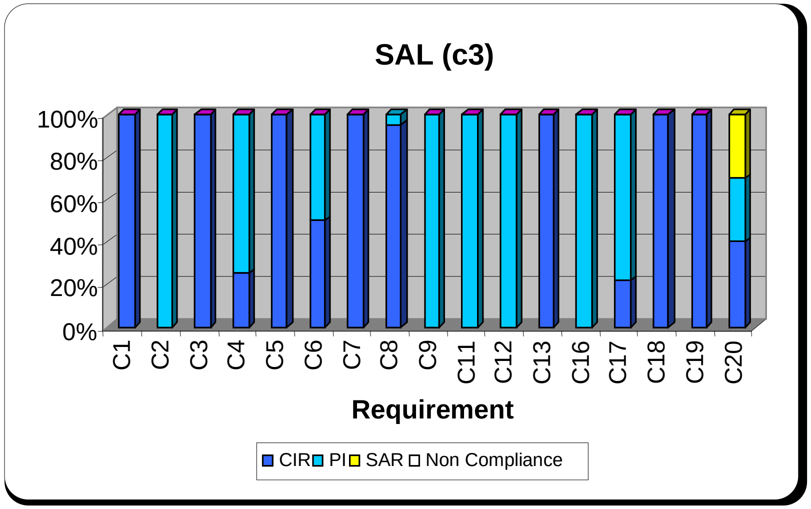


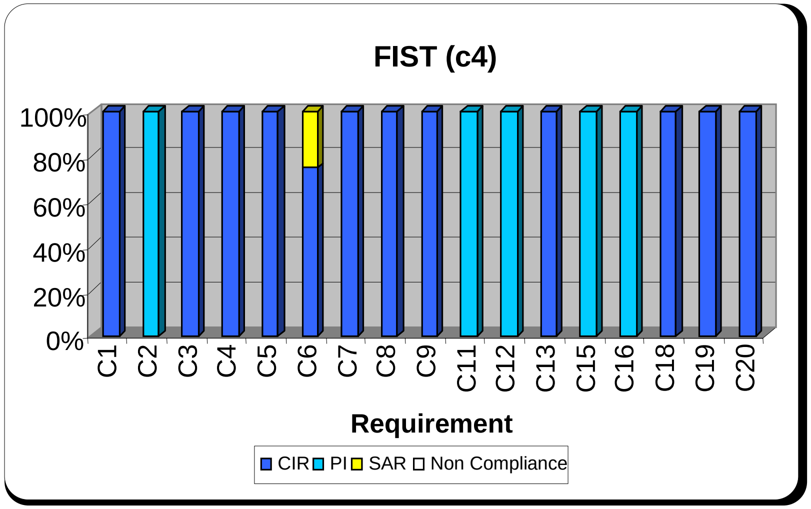
- All SRD requirements are met by the combination of CIR and baseline PI provided hardware

- All SRD requirements are met by the combination of CIR and baseline PI provided hardware

C1: Test Section Dimensions	C5: Oxidizer Comp.	C9:IR Imaging	C13:Pressure Meas.	C17: Full Field Veloc
C2: Initial Fuel State & Ignition Mech.	C6: Fluid Flow	C10: UV Imaging	C14: Chem. Comp.	C18: Accel. Meas.
C3: Acceleration and Vibration	C7: Number & Duration of Tests	C11: Temp.Point Meas.	C15: Radiometry	C19: Data Management
C4: Pressure & Temperature	C8: Visible Imaging	C12: Temp. Field Meas	C16: Velocity Point Meas.	C20: Simultaneous Meas.

Science Requirements Compliance



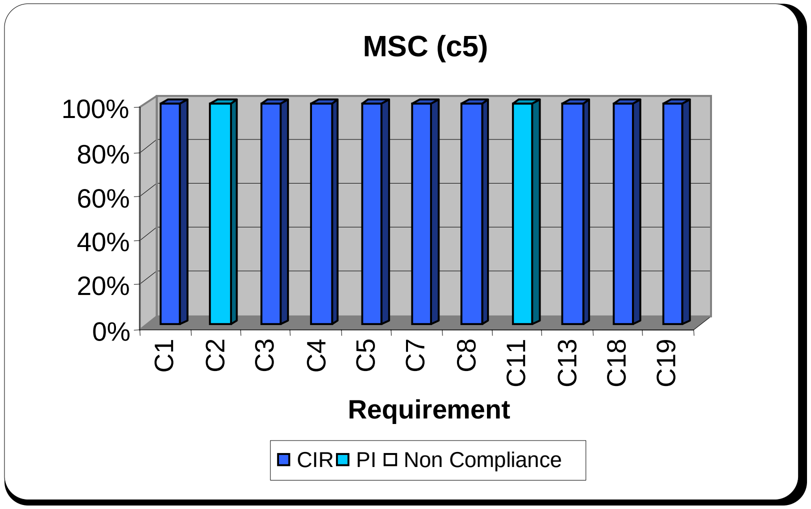


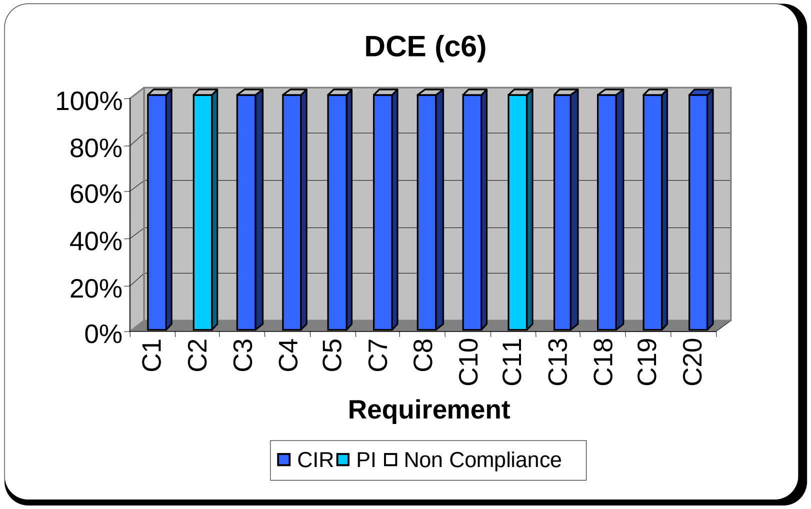
- Full compliance can be achieved by locating IPP in the SAR
- Additional IPP may be necessary to fully support all imaging acquisition requirements

- Flow rate capability vs. number of test points could be met if gas bottles are located in the SAR. This will require design modification for acceptable rack to rack fluid lines

C1: Test Section Dimensions	C5: Oxidizer Comp.	C9:IR Imaging	C13:Pressure Meas.	C17: Full Field Veloc
C2: Initial Fuel State & Ignition Mech.	C6: Fluid Flow	C10: UV Imaging	C14: Chem. Comp.	C18: Accel. Meas.
C3: Acceleration and Vibration	C7: Number & Duration of Tests	C11: Temp.Point Meas.	C15: Radiometry	C19: Data Management
C4: Pressure & Temperature	C8: Visible Imaging	C12: Temp. Field Meas	C16: Velocity Point Meas.	C20: Simultaneous Meas.

Science Requirements Compliance



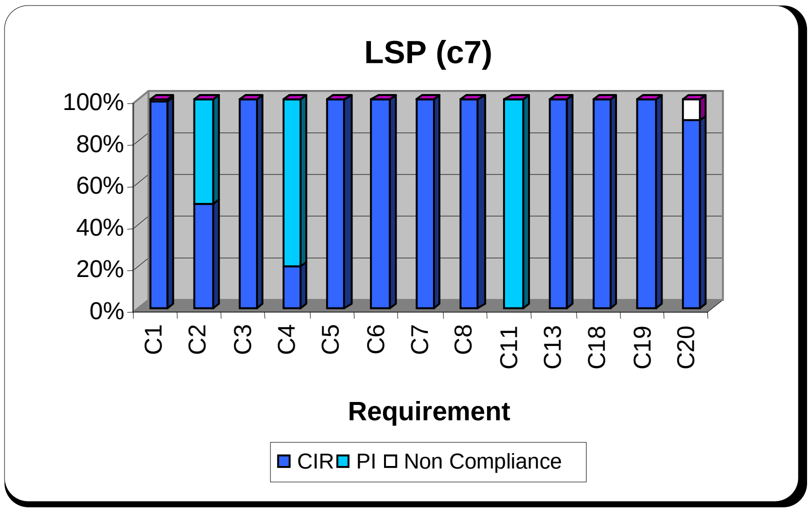


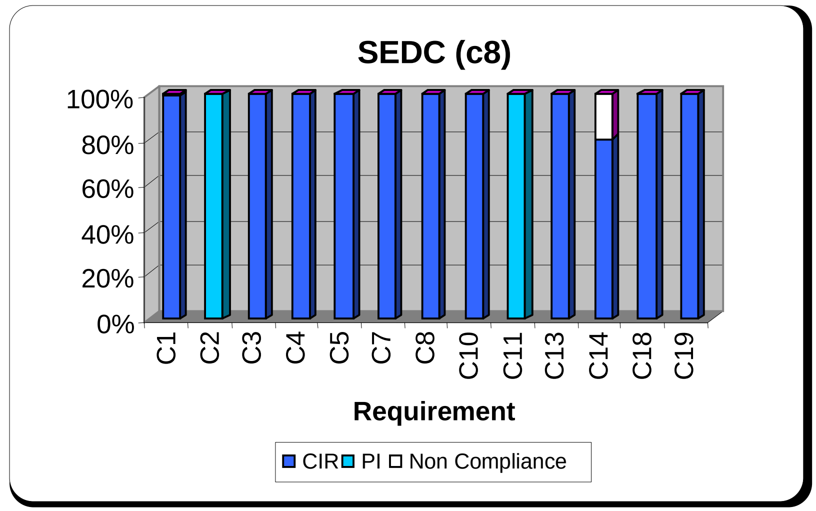
- All SRD requirements are met by the combination of CIR and baseline PI provided hardware

- All SRD requirements are met by the combination of CIR and baseline PI provided hardware

C1: Test Section Dimensions	C5: Oxidizer Comp.	C9:IR Imaging	C13:Pressure Meas.	C17: Full Field Veloc
C2: Initial Fuel State & Ignition Mech.	C6: Fluid Flow	C10: UV Imaging	C14: Chem. Comp.	C18: Accel. Meas.
C3: Acceleration and Vibration	C7: Number & Duration of Tests	C11: Temp.Point Meas.	C15: Radiometry	C19: Data Management
C4: Pressure & Temperature	C8: Visible Imaging	C12: Temp. Field Meas	C16: Velocity Point Meas.	C20: Simultaneous Meas.

Science Requirements Compliance



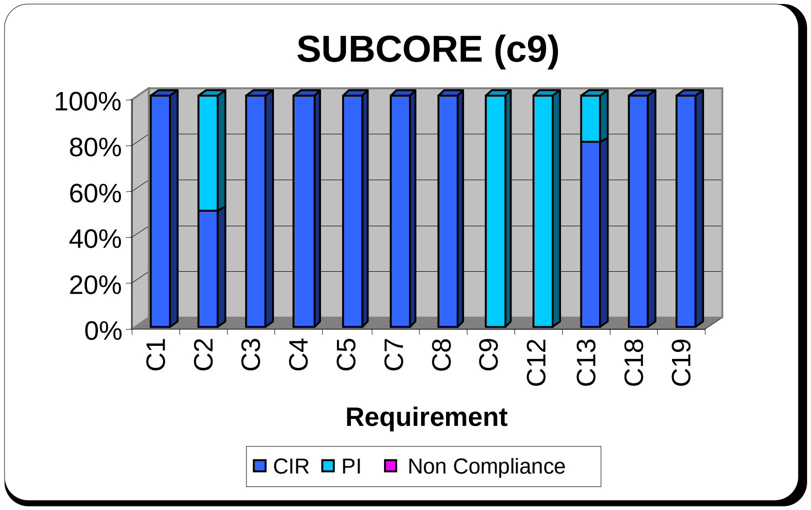


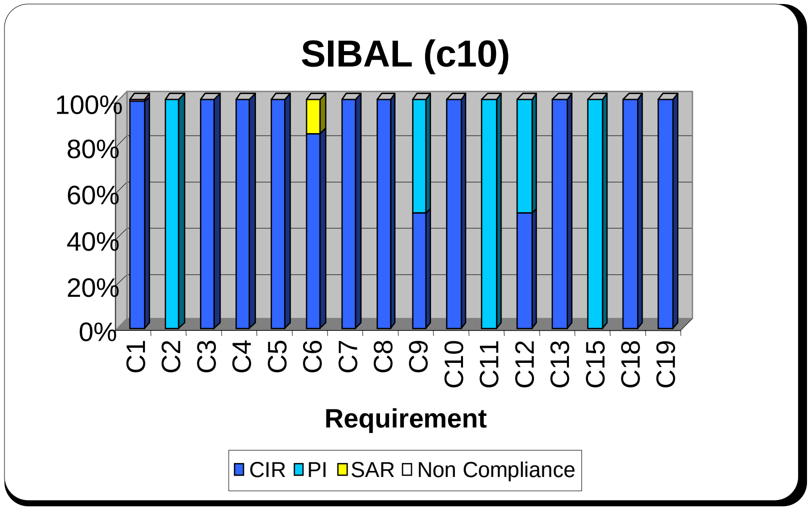
- CIR is not capable of simultaneously capturing Soot Volume Fraction and Soot Temperature data due to liquid crystal filter cycling time.

- Full resolution for chemical composition not satisfied for the required framing rate.
- Framing rate limited by the liquid filter cycling time
- Compliance may be achieved if individual packages are adopted to acquire SVF and ST data

C1: Test Section Dimensions	C5: Oxidizer Comp.	C9:IR Imaging	C13:Pressure Meas.	C17: Full Field Veloc
C2: Initial Fuel State & Ignition Mech.	C6: Fluid Flow	C10: UV Imaging	C14: Chem. Comp.	C18: Accel. Meas.
C3: Acceleration and Vibration	C7: Number & Duration of Tests	C11: Temp.Point Meas.	C15: Radiometry	C19: Data Management
C4: Pressure & Temperature	C8: Visible Imaging	C12: Temp. Field Meas	C16: Velocity Point Meas.	C20: Simultaneous Meas.

Science Requirements Compliance



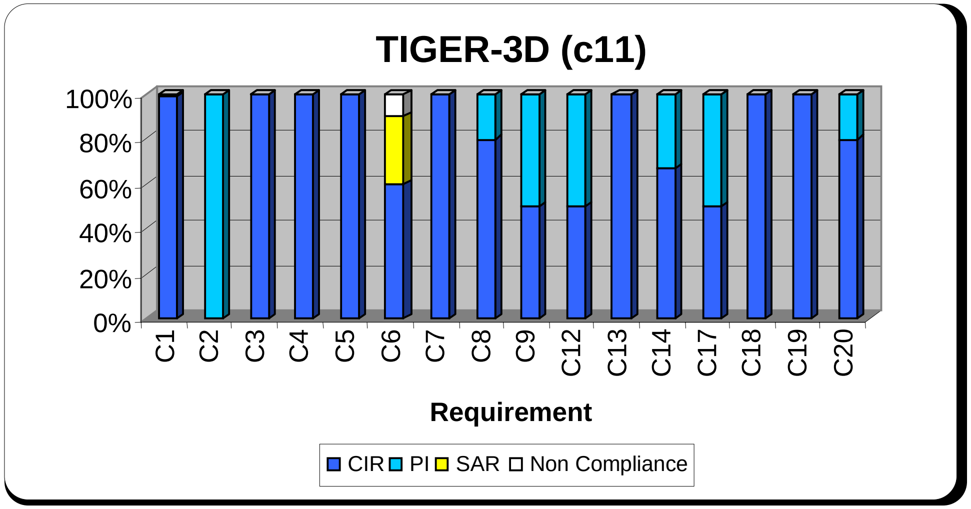


- All SRD requirements are met by the combination of CIR and baseline PI provided hardware

- Flow trough requirements and test durations can be further supported with SAR provided that rack to rack fluid lines are accepted
- Current exhaust vent design upgrade shows capability to support flow rate requirements for all test points if no filtering is required

C1: Test Section Dimensions	C5: Oxidizer Comp.	C9:IR Imaging	C13:Pressure Meas.	C17: Full Field Veloc
C2: Initial Fuel State & Ignition Mech.	C6: Fluid Flow	C10: UV Imaging	C14: Chem. Comp.	C18: Accel. Meas.
C3: Acceleration and Vibration	C7: Number & Duration of Tests	C11: Temp.Point Meas.	C15: Radiometry	C19: Data Management
C4: Pressure & Temperature	C8: Visible Imaging	C12: Temp. Field Meas	C16: Velocity Point Meas.	C20: Simultaneous Meas.

Science Requirements Compliance



- Unable to support some flow rates due to exhaust vent limitations:
  - Max. rate required: 240 SLM - Current design upgrades indicate that the EVP could handle 200 SLM
- Flow rates versus test durations could be achieved with SAR. This option is limited to:
  - acceptable rack to rack fluid line design
  - PI upmass allocation - Five 17.2L bottles (136Kg each) per test point are required - 20 test points in current SRD
- PI must provide suitable high frame rate color camera. Current technology may not support framing rate requirement

C1: Test Section Dimensions	C5: Oxidizer Comp.	C9:IR Imaging	C13:Pressure Meas.	C17: Full Field Veloc
C2: Initial Fuel State & Ignition Mech.	C6: Fluid Flow	C10: UV Imaging	C14: Chem. Comp.	C18: Accel. Meas.
C3: Acceleration and Vibration	C7: Number & Duration of Tests	C11: Temp.Point Meas.	C15: Radiometry	C19: Data Management
C4: Pressure & Temperature	C8: Visible Imaging	C12: Temp. Field Meas	C16: Velocity Point Meas.	C20: Simultaneous Meas.

Science Requirements Compliance Summary

The combination of CIR and PI hardware

- Fully complies with requirements C1 through C20 for experiments c1, c2, c5, c6, c7, c8 and c9
- Will comply with requirement C20 for experiment c3 by placing IPPs in the SAR
- Fully complies with the applicable operation requirements O4(hardware verification), O5 (experiment parameters monitoring), O7 (down/up link capability), O8 (data storage) and O9 (off-nominal condition verification) for experiments c1 through c11

- The addition of the SAR could increase compliance for experiments c4, c10 and c11. Considerations to design of rack to rack fluid lines and total PI upmass for gas supply are necessary.

Issues

- Need to increase max. flow rate supported by the EVP. Current design options indicate that exhaust vent system capability can be increased to support flow rates up to 200 SLM if no filtering is required.
- Need to work with c7 and c8 science teams to resolve simultaneous field measurements requirement avoiding the use of additional cameras
- Consideration must be given to power requirements of the c4/heater and c11/CO_2 laser.
- c11 power requirements concern in addition to gas supply (upmass) and data acquisition requirements indicate that this experiment will be very difficult to accommodate in FCF/CIR.

Science Assessment

Karen Weiland

Science Assessment Process

- **A science assessment at the CIR PDR is provided by the FCF Combustion Science Manager, similar to what the PI would do at an experiment PDR. The review was conducted by members of the Microgravity Combustion Science Branch and the National Center for Microgravity Research and is based on the SRED, FCF BCD, CIR BSD, and reports from individual packages.**

- **Summary of major findings is presented at this Review meeting.**

- **Final reports from reviewers are expected by April 19. Strengths, weaknesses, and recommendations to eliminate weaknesses will be collated and forwarded by April 23 to the appropriate managers.**

FOMA Design

Strengths

- **Gas supply for several chamber fills or many minutes of flow depending on flow rate and oxygen percentage.**
- **Capability of on-orbit mixing by both partial pressure and dynamic blending mixing.**
- **Cleanup of combustion products through a filter.**
- **Venting to space.**

Weaknesses

- **Oxidizer gas flow rate does not meet SRED requirement.**
  - **Supply and vent line limited to 90 sLm.**
- **Cleanup filter limited to 20 sLm.**
- **Verification methods are not defined for determining what is acceptable for venting during dynamic venting and post-combustion operations.**

Chamber Design

Strengths

- Chamber size and volume.
- On-orbit opening and resealing of chamber, pressure containment from vacuum up to 9 atm, and double seal design for containment of critical hazards.
- Multiple windows with large diameters. On-orbit replaceable windows.
- Capabilities for injecting gaseous fuels and oxidizers
- Feedthroughs for power, data, and control lines, and water cooling.
- Modular design and access to components, and smooth interior surfaces.

Weaknesses

- Window materials are not baselined for all spectral wavelengths specified in the SRED.
- Flexibility could be further improved with additional window port(s).

Optics Bench and Diagnostics Design

Strengths

- **Modular design for access to both sides of the optics bench.**
- **Modular design for diagnostic mounts and connectors. Universal connectors allow easy relocation. Prepackaged format minimizes crew time for installation.**
- **Digital imaging devices and storage. Digitally controlled cameras.**
- **Large data storage capacity.**

Weakness

- **Synergism between and commonality of FCF components, such as diagnostics, are lacking.**
- **Documentation of the diagnostic packages lags other packages.**

Flight and Ground Operations and Utilization

Strengths

- Flight operations plans and concepts drafted and fit with the hardware and software design.
- Template for PI Integration drafted. Schedules are being drafted to mesh with PI experiment development schedules.
- Mission Evaluation Requests submitted for experiments though 2003.
- Plans for ground operations, including physical space, support hardware, and simulators, are in draft stage or beyond.
- Telescience operations allow experiments to proceed with limited crew time, and provide data to the ground for debugging, data reduction and analysis, and replanning of future test points.

Weakness

- Data downlinking rate from ISS appears to be a limiting resource.

Major Conclusions

- The CIR is a path-breaking, modular facility that is eagerly anticipated by the user community.
- The preliminary design of the CIR can meet the science requirements needed to accomplish a large variety of microgravity combustion experiments in a timely fashion.
- The CIR design is ready to proceed to the critical design phase.
- Known design risks will be eliminated through evaluation and implementation of current mitigation plans and additional recommendations.

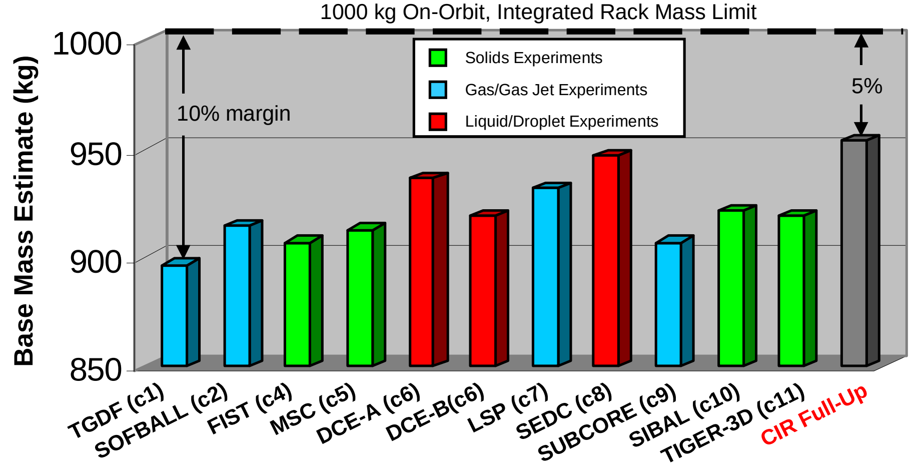
Miscellaneous Topics

Bob Zurawski
Dennis Rohn

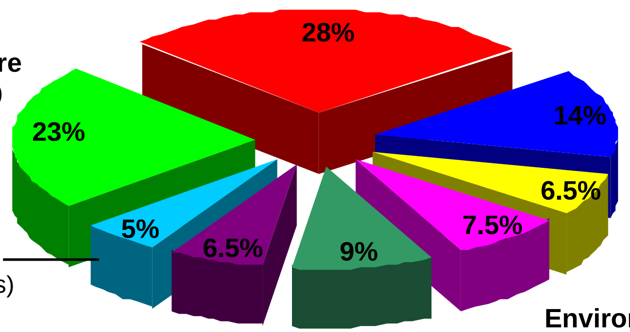
Combustion Integrated Rack Mass

- CIR-RPT-0007 documents CIR mass properties. PDR mass estimate is good fidelity, based on measured masses of mock-up/EM hardware, vendor data and analysis of Pro-E models.
- CIR operating configuration mass varies from experiment to experiment due to installation of different diagnostics, gas bottles, chamber inserts, PI H/W, etc.
- Margin in CIR operating configuration mass versus 1000 kg on-orbit, integrated rack limit is currently 5 to 10%, depending upon operating configuration.

CIR Operating Configurations - Mass Summaries



Mass Breakdown by CIR Element / Subsystem



- Majority of CIR mass is not discretionary (i.e., ISS hardware, CIR rack infrastructure hardware, etc.)
- CIR mass properties control plan;
  - Maintain high fidelity mass estimate based on measured masses where possible, or analysis from Pro-E models
  - Margin in element/component estimates
  - Move avionics ORUs to SAR after it is deployed, where practical.
- Effect of >804 kg CIR operating configuration mass on ARIS not expected to be a problem, but needs study.

Combustion Integrated Rack Metrics -- Mass

CIR Operating Configuration Mass Summary[1]

Assembly	Base Estimate (Kg)	Percent of Total
Optic Bench Assembly	115.23	12%
Optic Bench I/F Hardware	24.44	3%
Test Chamber Assembly	125.16	13%
PI Chamber Insert	40.00	4%
Color Camera	8.27	1%
HFR/HR Camera	14.69	2%
UV Cameras (2)	14.32	2%
HiBMS	11.73	1%
Illumination	13.06	1%
IPP A	21.50	2%
IPP B	21.50	2%
PI-Specific Electronics	10.32	1%
FOMA	85.37	9%
FOMA FCU	10.32	1%
FOMA Bottle (3.8L)	10.50	1%
FOMA Bottle (2.25L)	7.50	1%
FOMA Bottle (3.8L)	10.50	1%
FOMA Absorptive Filter (Large)	4.70	0%
Gas Chromatograph	14.97	2%
CIR Service Umbilical Set	5.17	1%
Rack Assembly	141.43	15%
ARIS	67.71	7%
I/O Processor	34.84	4%
Electrical Power Subsystem	57.77	6%
SAM Subsystem	0.85	0%
Water Distribution & Control Assy	20.37	2%
Air Thermal Control Assembly	37.44	4%
Fire Detection & Suppression Assy	2.66	0%
Gas Interface Assy	10.87	1%
Rack/Station I/F Umbilical Set	10.66	1%
GROSS TOTALS	**953.85**	
Integrated Rack Limit	**1000.00**	
Margin	**5%**	

CIR Launch Configuration Mass Summary[2]

Assembly	Base Estimate (Kg)	Installed for Launch
Optic Bench Assembly	115.23	Y
Optic Bench I/F Hardware	24.44	Y
Test Chamber Assembly	125.16	Y
PI Chamber Insert	--	N
Color Camera	--	N
HFR/HR Camera	--	N
UV Cameras (2)	--	N
HiBMS	--	N
Illumination	--	N
IPP A	--	N
IPP B	--	N
PI-Specific Electronics	--	N
FOMA	85.37	Y
FOMA FCU	--	N
FOMA Bottle (3.8L)	--	N
FOMA Bottle (2.25L)	--	N
FOMA Bottle (3.8L)	--	N
FOMA Absorptive Filter (Large)	--	N
Gas Chromatograph	--	N
CIR Service Umbilical Set	5.17	Y
Rack Assembly	141.43	Y
ARIS	67.71	Y[3]
I/O Processor	34.84	Y
Electrical Power Subsystem	57.77	Y
SAM Subsystem	0.85	Y
Water Distribution & Control Assy	20.37	Y
Air Thermal Control Assembly	37.44	Y
Fire Detection & Suppression Assy	2.66	Y
Gas Interface Assy	10.87	Y
Rack/Station I/F Umbilical Set	--	N
GROSS TOTALS	**729.3**	
Integrated Rack Limit (MPLM)	**804.00**	
Margin	**10%**	

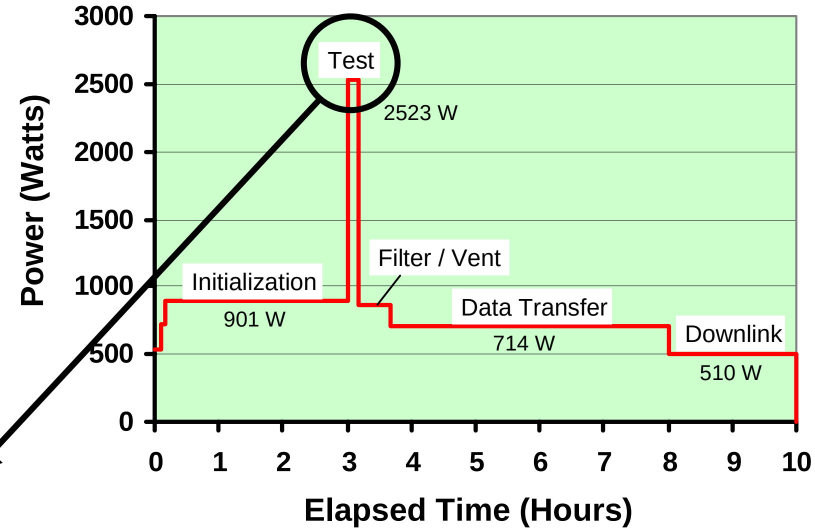
1. Operating configuration mass shown is for the full-up CIR (i.e., all UMLs utilized).

2. Items not installed in CIR are stowed for launch (e.g., foam-lined resupply lockers). CIR modular design permits quick installation of these items on-orbit.
3. Some ARIS components are installed on-orbit.

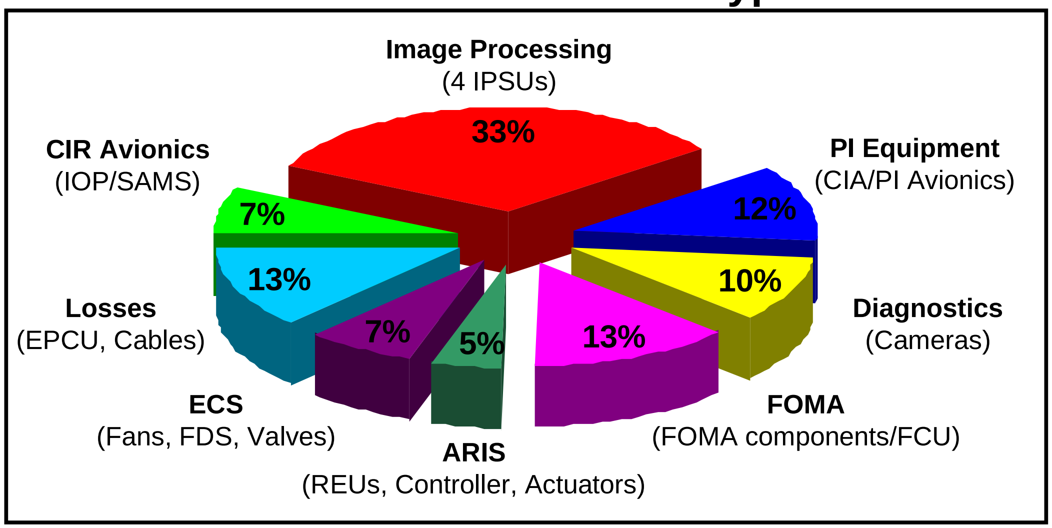
Combustion Integrated Rack Metrics -- Power

- CIR will typically operate ~10 hours for each combustion test, including initialization, test run, filter/exhaust, IPSU to IOP data transfer and data downlink.
- CIR power consumption during a typical combustion test will normally be less than 1 kW during the 10 hour operating period. During data downlink, only about 0.5 kW power is required.
- Peak power of ~2.5 kW is required only at the time of the burn, which will be seconds or minutes in duration. Peak power need is driven by avionics (i.e., image acquisition and storage). Other CIR items are relatively small power consumers.

Power Profile for a Typical Test



Peak Power Breakdown for a Typical Test*



* Peak power typically required only for 5-20 minutes during hours of operation for test.

- CIR power losses are minimized due to high conversion efficiency of EPCU (93%) & proper design of harnessing to minimize cable losses.
- ECS fans are variable speed to reduce power consumption while CIR is operating for many hours during initialization, data transfer and downlink of data.
- Significant power is saved by ISS if ARIS is commanded on/off and unlocked/locked by the crew shortly before and shortly after the burn, which typically lasts ~minutes.

Combustion Integrated Rack Metrics -- Power

CIR Operating Configuration* Power Summary

Assembly	Initialization (Watts)	Test (Watts)	Data Transfer (Watts)	Data Downlink (Watts)
Input/Output Processor	155.0	155.0	155.0	155.0
Image Processing & Storage Units (4)	0.0	820.0	187.5	0.0
Laptop Computer	0.0	0.0	0.0	0.0
SAMS	27.0	27.0	0.0	0.0
PI Avionics	0.0	200.0	0.0	0.0
PI Insert (Chamber)	0.0	100.0	0.0	0.0
Diagnostics (Cameras/Illumination)	0.0	264.0	0.0	0.0
FOMA Avionics (FCU)	168.0	168.0	0.0	0.0
FOMA	163.0	163.0	0.0	0.0
ARIS	123.0	123.0	123.0	123.0
WTCS - WFCA #1	10.0	10.0	10.0	10.0
WTCS - WFCA #2	0.0	10.0	0.0	0.0
ATCU	80.0	140.0	80.0	80.0
FDSS	20.0	20.0	20.0	20.0
Cable Losses (98% Efficiency)	15.2	44.9	11.7	7.9
EPCU Losses (93% Conv. Efficiency)	139.5	278.6	126.9	113.9
GROSS TOTALS	**900.7**	**2523.5**	**714.1**	**509.8**
Air Thermal Control (Watts)	673.0	2046.7	499.0	307.7
Water Thermal Control - L1 (Watts)	227.7	366.8	215.1	202.1
Water Thermal Control - L2 (Watts)	0.0	110.0	0.0	0.0
DURATION	**~3 hours**	**~10 minutes**	**~4.5 hours**	**~2 hours**

* Operating configuration power shown is for the full-up CIR (i.e., all UMLs utilized).

FCF Hardware Concept Review RFA Status

- 15 Request for Actions (RFAs) were submitted at the FCF Hardware Concept Review, June 30,1998
  - 12 were directed at the FCF System
  - 2 were directed at the CIR
  - 1 was directed at the FIR
- Closure process:
  - 1.) Response prepared, reviewed internally and updated as needed
  - 2.) Response sent to originator for review
  - 3.) Updated RFA closed by FCF Control Board Board
- The project response has been completed and reviewed internally for 12 of these
- The responses to 10 of the 12 have been reviewed and accepted by the RFA initiators. The remaining 2 are awaiting supporting information to be developed before they are sent to the initiators for concurrence.

HCR RFA Summary

#	Issue Summary	Response Summary	Status
1	Redesign FIR so that it can meet the 20-30° C nominal temp. requirement		Response in work
2	Clarify the video uplink capability between PIs and the crew	ISS plans limited capability at UF-1, plans upgrade by UF-5	Initiator concurs
3	Design to allow manual rotation of optics bench in case of motor failure	Design has been revised to eliminate the need for motorized operation	Waiting for a supporting drawing
4	Evaluate the rack-to-rack umbilicals from a protrusion standpoint and their impact on operations	A revised concept has been developed routing the umbilicals in the standoff area, eliminating any protrusions	Initiator concurs
5	Verify that no power is transferred over rack-to-rack umbilicals	Rack-to-rack umbilicals are all fiber optic, no power is transferred	Initiator concurs
6	Develop a Vibroacoustic Control Plan to assure appropriate microgravity level for payloads	A Microgravity Control Plan will be drafted which covers both ISS and Science microgravity disturbances	Waiting for draft of the Plan
7	Validate or revise the FCF goal of designing such that experiments average < $2M	FCF believes the $2M (1995 dollars) is still a valid number to design to.	Response in work. Planing a more detailed analysis of basis experiments
8	CIR Compliance Matrix for flow velocities assumes a cross sectional area. Clarify FCF volumetric capability and leave velocity up to experiment configuration	Compliance has been revised to reflect FCF volumetric capabilities for three different types of flow and that the resulting velocity is a function of the experiment design	Initiator concurs

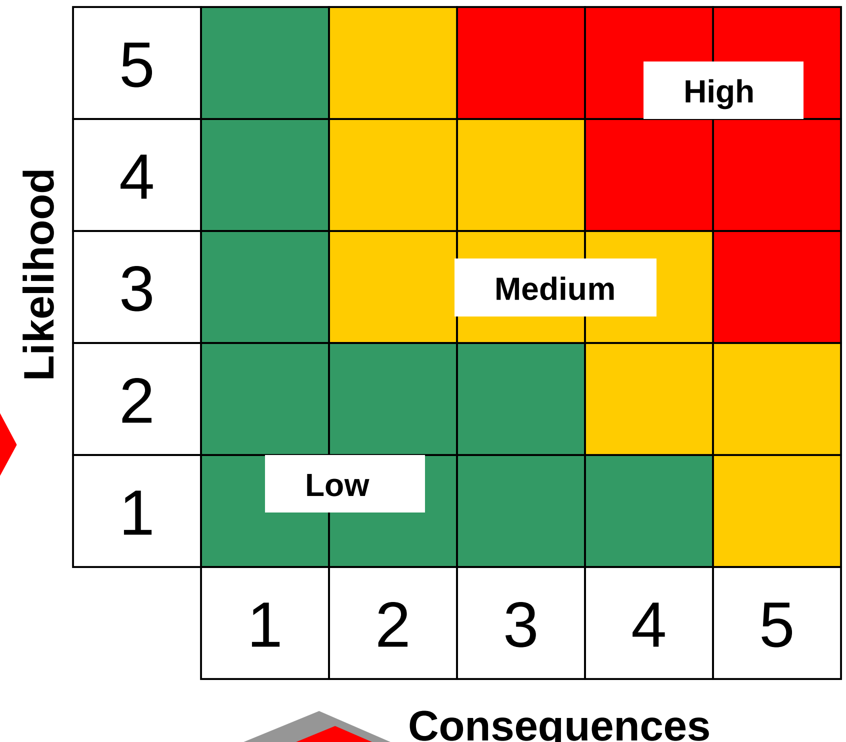
HCR RFA Summary

#	Issue Summary	Response Summary	Status
9	CIR Compliance Matrix for max. O2 concentration does not account for potential increases due to experiment equipment	Compliance matrix has been updated to clarify where the O2 limits apply and that experiments could achieve higher levels with the appropriate equipment	Initiator concurs
10	Clarify the Compliance Matrix philosophy. Is FCF allowed to "comply with PI hardware," or must FCF fully meet the requirement on its own?		Response in work
11	Consider a plan to carry spares for most common IOP cards	Logistics support analyses will identify what spares should be carried	Initiator concurs
12	Develop a card "swap-out" plan for the IOPs, Have onboard BITE that can detect to board level	Internal IOP BIT will poll boards to detect problems. Logistics support analyses will identify if additional test ability is needed	Initiator concurs
13	Adapt Fluids diagnostic bases, so that they can be using in the CIR	A Working Group is in the process of making diagnostic architecture as common as possible between the racks	Initiator concurs
14	Assess if FIR & CIR can be placed on either side of SAR, vs. fixed locations	FIR & CIR can be located on either side of SAR	Initiator concurs
15	Discuss optics bench foldout concept with PSRP to assure safe design	Concept has since been revised to be more safe, reviewed with crew & PSRP	Initiator concurs

CIR Risk Management

- Developed a formal Risk Management Plan FCF-PLAN-0007 which establishes structured risk management processes.
- Established a risk database to track and control project risks.

CIR Risk Matrix



Likelihood:

The Current Process:

5	**Can not prevent the event and No alternate approaches are available**
4	**Can not prevent the event but alternate approaches are available**
3	**May prevent the event Additional actions are required**
2	**Usually sufficient to prevent the event**
1	**Sufficient to prevent the event**

Consequences:

1	2	3	4	5
Minimal or no impact.	Moderate reduction in capability. Same approach retained.	Moderate reduction in capability. Workarounds required.	Major reduction in capability. Workarounds required.	Unacceptable reduction in capability. No workarounds available.

CIR Risks

RISK

L=5, C=4	Category: High

ISS, science or other requirements changes impact CIR design

- ☑ **Maintain awareness of proposed requirements changes and continue support for ISS PIRN evaluation activity.**
- ☑ **Coordinate with PIs and project scientists to define specific experiment SRD requirements**

RISK

L=5, C=3	Category: High

FOMA flow capability may not meet science requirements in SRED or SRDs

- ☑ **Design concept to modify EVP to support 200 SLP with no filtering.**
- ☑ **Add bottle capacity and high flow capacity GSDP to SAR when deployed. Develop rack-to-rack fluid interface and investigate its feasibility.**
- ☑ **Coordinate with PI teams to define specific experiment SRD flow and exhaust requirements**

CIR Risks

RISK

L=3, C=5	Category: High

CIR may not meet ISS requirements to vent combustion by-products

- ☑ **JSC M&P group to extend acceptable vent gasses by specifying concentration limits and duration periods for materials currently identified as incompatible.**
- ☑ **Support ISS PIRN activity.**
- ☑ **CIR filtering of gases prior to vent.**
- ☑ **Characterization of combustion by-products in ground testing and constraints placed on PI Combustion by-products, if necessary.**

RISK

L=3, C=4	Category: Med

CIR may not meet ISS Micro-gravity and Acoustic noise requirements

- ☑ **Develop Acoustic and Micro-gravity control plans. Draft documents have been developed.**
- ☑ **Design awareness of requirements. Design philosophy minimizing use of rotating equipment, cold plates and use of isolation mounts.**
- ☑ **Perform acoustic and micro-gravity tests on CIR components. Develop finite element and statistical energy models for CIR**

CIR Risks

RISK

L=3, C=4	Category: Med

Mass of the CIR on-orbit configuration may exceed 1000 Kg ISS rack limit

- ☑ All experiment configurations modeled have base masses below the 1000 Kg limit. 5-10% margin (depending upon operating configuration) exists at PDR versus the 1000 kg limit.
- ☑ CIR is designing to permit relocation of CIR avionics ORUs to SAR after deployment of that rack to ISS.
- ☑ Investigate use of lightweight castable material for stowed ORUs.
- ☑ Structural margin in Optics Bench also allows for mass reduction, if necessary.

RISK

L=2, C=5	Category: Med

On-orbit maintenance procedures may not adequately clean-up the combustion chamber

- ☑ Early testing of proposed clean-up and maintenance procedures and hardware.
- ☑ Constraints on PI contamination of combustion chamber.

CIR Risks

RISK

L=5, C=2	Category: Med

Software and electronic/mechanical components become obsolete over the 10+ year life of the CIR

- ☑ Modular design allows maximum of replaceable parts
- ☑ Software is changeable by uplink

RISK

L=5, C=2	Category: Med

Radiation effects on commercial grade electronic components cause destructive and non-destructive SEE

- ☑ Provide cold spares for high risk ORUs
- ☑ Perform board-level proton tests of high risk hardware. (Indiana University or University of California at Davis)
- ☑ Implement watch-dog timer functions in hardware to cycle power on lock-up

CIR Risks

RISK

L=3, C=3	Category: Med

Inability of CIR to meet ISS radiated EMI requirements

- ☑ Design awareness of requirements. Design philosophy which controls grounding and implements shielding. Use of custom power supplies and minimal use of rotating equipment.
- ☑ Perform CIR component and sub-system level EMI tests.

RISK

L=3, C=2	Category: Med

High packaging density causes interferences between CIR structural elements

- ☑ Pro-E solid modeling design S/W provides high probability of identifying interferences before hardware is built
- ☑ Design maturity has reduced IOP discrete and analog I/O requirements. Investigate redesign to eliminate current interference
- ☑ Current design does not allow installation of IPP at UML-1. This presents an operational limitation only, no science requirements for this configuration.
- ☑ Current design does not allow HFR/HR package at UML-1. This presents an operational limitation only, no science requirements for this configuration. Investigate design options to minimize the size of this package

CIR Risks

RISK

L=3, C=2	Category: Med

May not achieve science data downlink requirements due to bandwidth and HRDL availability

- ☑ Timeline operations to optimize downlink allocations
- ☑ Investigate use of digital compression to minimize downlink requirements
- ☑ Coordinate with PI teams to refine science data downlink requirements

RISK

L=2, C=3	Category: Low

Reliability and maintainability assessments cause redesign of CIR.

- ☑ Perform reliability assessment post-PDR
- ☑ Perform maintainability assessment post-PDR
- ☑ Design philosophy with emphasis on modularity

CIR Risks

RISK

L=2, C=2	Category: Low

System re-design caused by incomplete stress, dynamic, and fracture analysis

- ☑ **Analysis performed according maturity of sub-system designs**
- ☑ **Stress analysis has been completed on the major structural components of the CIR - Optics Bench, Combustion Chamber, Chamber Windows, and Rack Door**
- ☑ **Fracture analysis for chamber and window materials will be performed post-PDR**

RISK

L=2, C=2	Category: Low

ARIS performance and life affected by CIR operational mass above 804 Kg.

- ☑ **Initial discussion with Boeing indicates that 1000 Kg rack may be accommodated. Initiate performance analysis with regard to CIR mass, natural frequency at 18 Hz, and variable Cg .**
- ☑ **Combustion experiments require only short periods of isolation. Investigate operational scenarios which minimize impacts to ARIS**

CIR Risks

RISK

L=1, C=4	Category: Low

CIR design may not be able to meet launch load requirements

- ☑ Current analysis of rack shows 22 Hz natural frequency, requirements is to be above 25 Hz. A coupled loads analysis may show compatibility with requirements.
- ☑ Increase rack stiffness through re-design of rack attachment hardware. Investigate re-design options to improve structural load paths
- ☑ Current design exhibits high fastener loads at the ATCU rack attachment point. Investigate re-design option to improve structural load paths. Investigate use of a pin between the IOP and optics bench

RISK

L=1, C=3	Category: Low

May not be able to qualify window materials to pressure and spectral range requirements

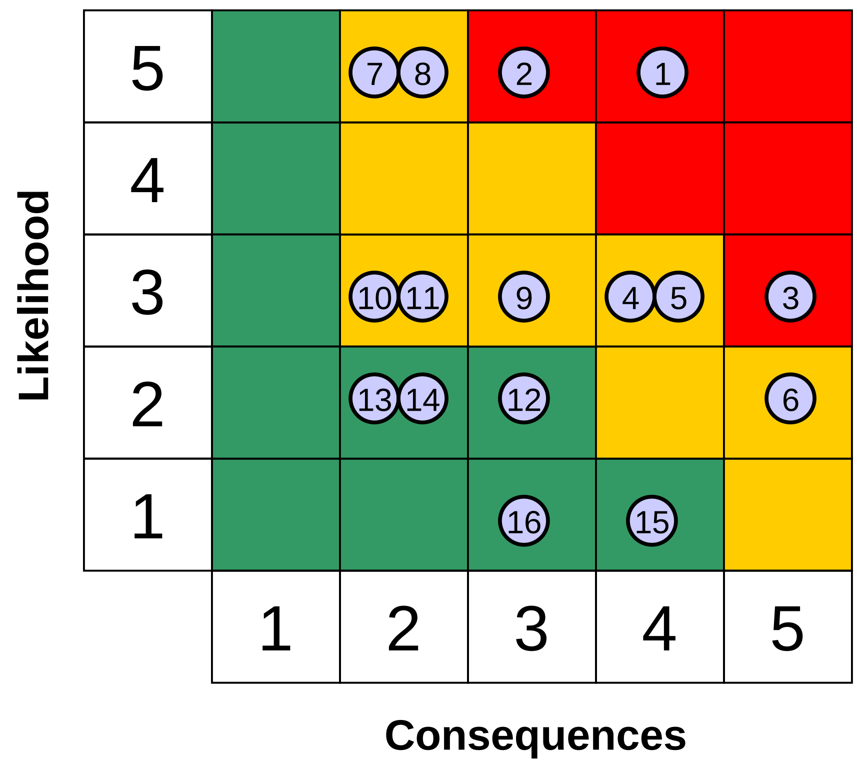
- ☑ Initial fracture and stress analysis indicate suitable material properties. Initiate fracture tests to meet qualification requirements

CIR Risk Assessment Summary

RISK:

1) **ISS, science or other requirements changes**
2) **FOMA flow capability**
3) **Vent combustion by-products**
4) **Micro-gravity and acoustic noise requirements**
5) **On-orbit mass exceeds 1000 Kg ISS rack limit**
6) **Combustion chamber maintenance procedures**
7) **Software/component obsolescence**
8) **SEE effect on commercial grade electronics**
9) **EMI requirements**
10) **Interferences between CIR structural elements**
11) **Science data downlink requirements**
12) **Reliability and maintainability assessments**
13) **Incomplete stress, dynamic, and fracture analysis**
14) **ARIS performance above 804 Kg**
15) **Launch load requirements**
16) **Qualification of window materials**

CIR Risk Matrix



CIR PDR Summation

- ☑ Is the proposed CIR Hardware Design approach technically sound to proceed with acceptable risk with incremental production and assembly of the CIR engineering model?

- ☑ Is the maturity of CIR Software and the proposed software spiral development approach adequate?

  Are the right software tools being employed?

- ☑ Based on an incremental development approach, are other aspects of the CIR, including interface definition, operations concepts, utilization plans, support engineering, science requirements compliance and technical documentation adequate to proceed with detailed design and development of the CIR?

Management Discussions

Jack Salzman

Ed Winsa

Bob Zurawski

PDR Review Board Caucus and Discussion

Ralph Carruth

Review Board Members

ACRONYMS

AC	Assembly Complete
ARIS	Active Rack Isolation System
ATCS	Air Thermal Control System
ATCU	Air Thermal Control Unit
BCD	Baseline Concept Description
BSD	Baseline System Description
C&C	Command and Control
C&DH	Command and Data Handling
CCD	Charge Coupled Device
CDIP	Command and Data Interface Package
CDMS	Command and Data Management Subsystem
CIDS	Critical Item Development Specification
CIR	Combustion Integrated Rack
CM	Combustion Module (in reference to Combustion Module-I)
CM	Compliance Matrix
COTS	Commercial Off The Shelf
CP	Chamber Package
CTB	Collapsible Transfer Bags
DARTFire	Diffusing & Radiative Transport Controlled Fire
DCE	Droplet Combustion Experiment
E&TS	Engineering & Technical Services Directorate
ECS	Environmental Control System
EDAC	Error Detection and Correction
EEE	Electrical, Electronic, and Electromechanical
EM	Engineering Model
EMI	Electromagnetic Interference
EPCU	Electrical Power Control Unit
EPS	Electrical Power System
ESP	Electronic Support Package
EVP	Exhaust Vent Package
EWT	Embedded Web Technology
FCF	Fluids and Combustion Facility
FCU	FOMA Control Unit
FDSS	Fire Detection and Suppression System
FIR	Fluids Integrated Rack
FLAP	Facility Laptop
FOMA	Fuel/Oxidizer Management Assembly
GC	Gas Chromatograph
GDP	Gas Delivery Package
GIS	Gas Interface System
GIU	Ground Integration Unit
GPVP	Generic Payload Verification Plan
GRC	Glenn Research Center
GSE	Ground Support Equipment
GUI	Graphical User Interfaces
HEDS	Human Exploration and Development of Space

HFR	High Frame Rate
HiBMs	High Bit Depth/Multispectral
HR	High Resolution
HRDL	High Rate Data Link
HRFM	High Rate Frame Multiplexer
HRL	High Rate Link
HTTP	Hypertext Transfer Protocol
ICD	Interface Control Document
IDD	Interface Definition Document
IDL	Interface Definition Language
I/O	Input/Output
IOP	Input/Output Processor
IPP	Image Processing Package
IPSU	Image Processing and Storage Units
IRD	Interface Requirements Document
IRR	Interface Resource Ring
ISPR	International Standard Payload Rack
ISS	International Space Station
ISSP	International Space Station Program
ITCS	ISS Internal Thermal Control System
JSC	Johnson Space Center
LLL	Low Light Level
LRDL	Low Rate Data Link
LSA	Logistics Support Analysis
MDM	Mutiplexer/Demultiplexer
MDP	Maximum Design Pressure
MER	Mission Evaluation Request
MFC	Mass Flow Controller
MRDL	Medium Rate Data Link
MRL	Moderate Rate Link
MRPO	Microgravity Research Program Office
MSAD	Microgravity Science and Applications Division
MSD	Microgravity Sciences Division
MSFC	Marshall Space Flight Center
MTA	Maintenance Task Analysis
MTL	Moderate Temperature Loop
NASA	National Aeronautics and Space Administration
ORU	Orbital Replacement Unit
OZ2	ISS PO Mission Integration and Planning
OZ3	ISS PO Hardware and Software Engineering Integration
PDR	Preliminary Design Review
PEHG	Payload Ethernet Hub Gateway
PFE	Portable Fire Extinguisher
PI	Principal Investigator
PIA	Payload Integration Agreement
PIDS	Prime Item Development Specification

PIV	Particle Image Velocimetry
PO	Payloads Office/Project Office
PSRP	Payload Safety Review Panel
PVP	Payload Verification Plan
QA	Quality Assurance
QD	Quick Disconnect
R&M	Reliability and Maintainability
RIP	Rack Interface Panel
RMSA	Rack Maintenance Switch Assembly
RPC	Remote Power Controller
RVE	Equivalent to $1m^3$
SAMS	Space Acceleration Measurement System
SAR	Shared Accommodations Rack
SBC	Single Board Computer
SD	Science Diagnostics
SDP	Safety Data Package
SRD	Science Requirements Documents
SRED	Science Requirements Envelope Document
STDCE	Surface Tension Driven Convection Experiment
TBD	To Be Determined
TSC	Telescience Support Center
UF	Utilization Flight
UIP	Utility Interface Panel
UML	Universal Mounting Location
US Lab	United States Laboratory Module
VES	Vacuum Exhaust System
VRS	Vacuum Resource System
WIP	Water Interface Panel
WTCS	Water Thermal Control System